FINAL

ACTION PLAN FOR THE CAMP EDWARDS IMPACT AREA GROUNDWATER QUALITY STUDY

MASSACHUSETTS MILITARY RESERVATION
CAPE COD, MASSACHUSETTS

Volume I - Text

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List of Acronyms and Abbreviations

ABB	ABB Environmental Services, Inc.
AFCEE	Air Force Center for Environmental Excellence
ANG	Air National Guard
AOC	Area of Concern
APC	Armored Personnel Carrier
APR	Air Purifying Respirator
ARAR	Applicable, Relevant, and Appropriate Requirements
ARNG	Army National Guard
CDM	Camp Dresser and McKee
CLP	Contract Laboratory Procedure
CS	Chemical Spill
DO	Dissolved Oxygen
DNT	Dinitrotoluene
EMT	Emergency Medical Technician
EPA	Environmental Protection Agency
ERI	Environmental Research, Inc.
FID	Flame Ionization Detector
GP	Gun Position
HASP	Health and Safety Plan
HE	High explosive
HMX	Cyclotetramethylenetetranitramine
IDW	Investigation Derived Waste
IRP	Installation Restoration Program
kg	Kilogram
LITR	Light inexpensive training round
LRWSPAT	Long Range Water Supply Process Action Team
MAARNG	Massachusetts Army National Guard
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
mg	Milligram
MMR	Massachusetts Military Reservation
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAD27	North American Datum 1927
NGVD	National Geodetic Vertical Datum
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PID	Photoionization Detector
PPB	Parts Per Billion

PPE	Personal Protective Equipment
PPM	Parts Per Million
PRE	Preliminary Risk Evaluation
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
QAPP	Quality Assurance Project Plan
RAH	Risk Assessment Handbook
RDX	Cyclonite
SA	Site Assessment
SOP	Standard Operating Procedures
SVOC	Semi-Volatile Organic Compounds
TAL	Target Analyte List
TCL	Target Compound List
TNT	Trinitrotoluene
USACHPPM	United States Army Center for Health Promotion and Preventive Medicine
USAEHA	United States Army Environmental Hygiene Agency
USGS	United States Geologic Survey
UXO	Unexploded Ordnance
VA	Veterans Administration
VOC	Volatile Organic Compound
WHPA	Well Head Protection Area

1.0 INTRODUCTION

The Army National Guard fully intends to partner with the Environmental Protection Agency (EPA) and other federal agencies to ensure a thorough, scientifically sound investigation of the effects of military operations on the groundwater beneath the Impact Area. By working with the EPA, the Massachusetts Department of Environmental Protection (MADEP), local officials and the citizens of Cape Cod, the Army National Guard (ARNG) pledges to complete the investigation and take the necessary steps to protect the environment of Cape Cod while providing realistic training for our citizen soldiers.

1.1 Background

In July 1996 the National Guard Bureau (NGB) and the Massachusetts Army National Guard (MAARNG) were directed by the Deputy Undersecretary of Defense for Environmental Security [DUSD(ES)] to study the effects of military operations on the groundwater beneath the Impact Area. This study was in response to concerns raised by EPA Region I in a letter to DUSD(ES).

In August 1996 NGB assembled experts from the Army, the Air Force, the MAARNG, the Army Corps of Engineers, the Army Environmental Policy Institute, Air Force Center for Environmental Excellence, Army Environmental Center, the Army Center for Health Promotion and Preventative Medicine and Georgia Institute of Technology to create an action plan to complete the study. Engineering Technologies Associates, Inc. was retained to write the action plan in accordance with the guidance provided by the working group.

In October 1996 the MAARNG began working with the Long Range Water Supply Process Action Team (LRWSPAT) on the development of the action plan.

In December 1996 a rough draft of the action plan was presented to the EPA, MADEP, and members of the LRWSPAT, which includes the EPA, MADEP, the Cape Cod Commission (CCC), and the water districts of Bourne, Falmouth, Mashpee, and Sandwich. The goal of this comment period was to solicit their input in the further development of the action plan. NGB requested comments be returned by 15 January 1997 so a final draft could be released for public review in March or April.

In February 1997 the action plan was drastically changed to address the comments received from the EPA, MADEP, and other members of the LRWSPAT and a Response to Comments was written. On February 19, NGB and MAARNG arranged for explosives experts to brief the LRWSPAT. After this meeting, NGB and MAARNG met with EPA and MADEP. NGB and MAARNG agreed to complete and release the Response to Comments and a comment resolution workshop was scheduled for March 17, 1997. After the workshop the final draft plan would be released for public comment.

On February 27, 1997 EPA Region I released an Administrative Order directing the NGB to prepare the work plan, which had previously been submitted to the EPA, MADEP, CCC, and the LRWSPAT, for a comprehensive investigation of the groundwater beneath the Impact Area. The Administrative Order provides for complete EPA oversight and participation and establishes a citizens advisory committee to monitor the work.

On March 3, 1997 the Chief of National Guard Bureau met with EPA Region I and pledged the NGB's full cooperation and support. On March 7, 1997 NGB presented the concept of the action plan to the EPA, MADEP, and other members of the LRWSPAT and discussed comments received from the EPA, MADEP and the Cape Cod Commission. This discussion, along with the Administrative Order, guided the final development of the draft action plan, released to EPA, MADEP and the public on March 14, 1997.

The Draft Action Plan was revised based on comments received from EPA, MADEP, and other stakeholders. NGB met with these parties on May 1, 1997 and received written comments from

EPA on April 22, and May 8, 1997. The Draft Final Action Plan based on these comments and meetings was submitted to EPA on May 17, 1997.

This Final Action Plan is based on comments received from EPA, MADEP, and other stakeholders in May and June 1997. NGB met with the Impact Area Citizens Review Team on May 20, and June 9, 1997. NGB met with the EPA on May 29, and with the EPA, MADEP, and other stakeholders on June 18, and June 26, 1997. Written comments were received from MADEP and other stakeholders in June, and from the EPA on July 3, 1997.

1.2 Overview

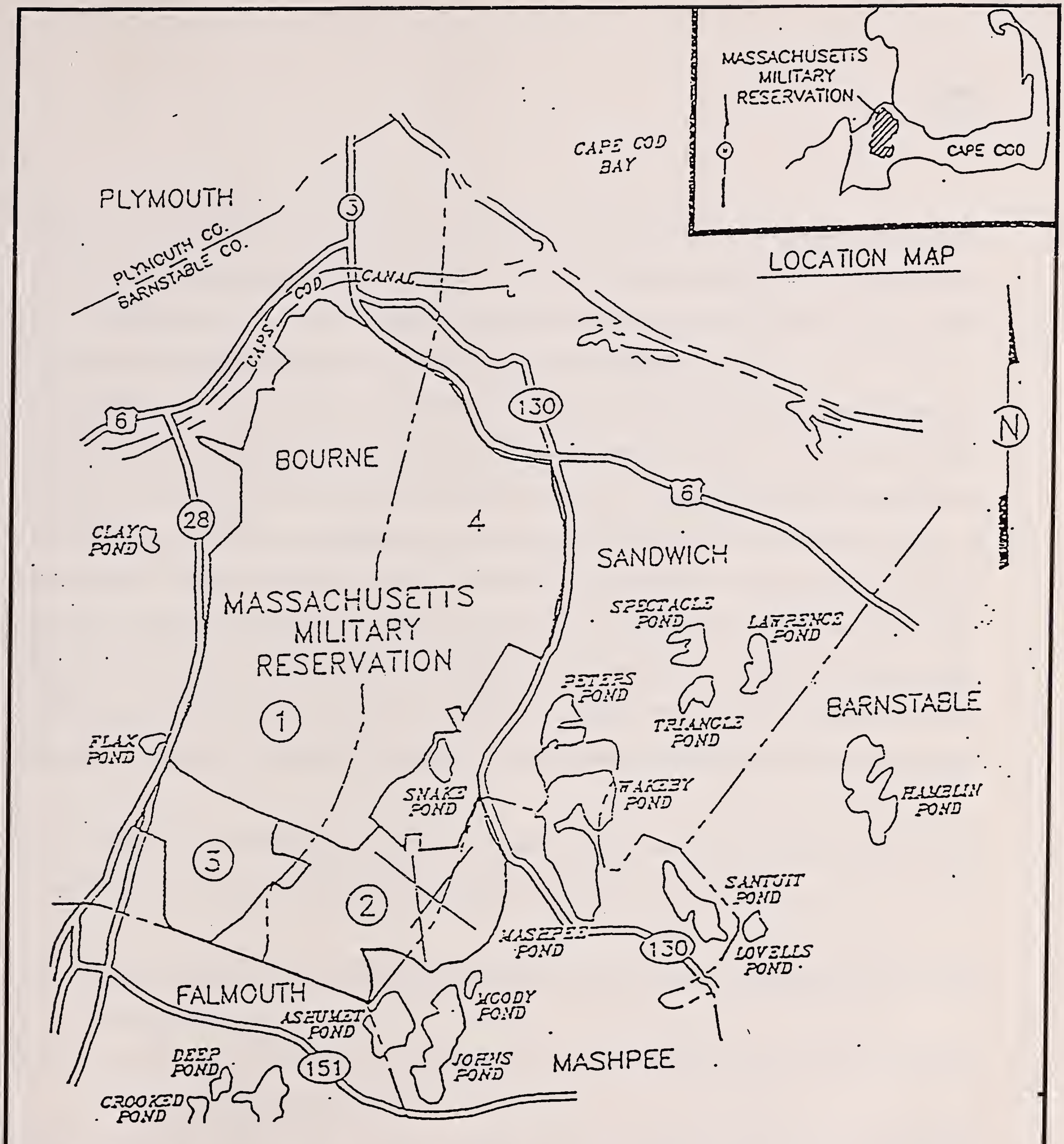
The Massachusetts Military Reservation (MMR) is a 21,000 acre facility located in western Cape Cod in the towns of Bourne, Falmouth, Mashpee and Sandwich in Barnstable County (Figure 1-1). The facility is organized into four functional areas:

(i) The Cantonment Area: The most actively used section, it consists of the base administrative, housing, maintenance and operation facilities (Area 2 on Figure 1-1);

(ii) The Training Range and Impact Area: Occupies most of the northern portion of the base, and is used for military training, law enforcement training and sport shooting (Area 1 on Figure 1-1);

(iii) The Veterans National Cemetery: Located in the southwestern corner of MMR, it contains a Veterans Administration (VA) Cemetery and support facilities (Area 3 on Figure 1-1), and

(iv) Cape Cod Air Force Station: Occupies the northeastern portion of the range area, and houses the air defense warning system (Area 4 on Figure 1-1).



LEGEND

1 RANGE MANEUVER AND IMPACT AREA
2 CANTONMENT AREA
3 MASSACHUSETTS NATIONAL CEMETERY
4 CAPE COD AIR FORCE STATION
(PAVE-PAWS)

Source: Aneptek, 1995

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MMR IMPACT AREA WORKPLAN
FIGURE 1-1
MMR LOCATION MAP

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Military use of MMR dates back to 1911, with the most intensive use of the facility occurring during and immediately after World War II. Most activities have been phased out to the current level consisting of the Otis Air National Guard Base airfield and military support facilities like the Veterans National Cemetery and the training range and Impact Area.

The training range and Impact Area has been used for Army National Guard, law enforcement and fire protection training. Law enforcement training consists of small arms firing at several ranges within the study area. The fire protection training involved training exercises with military and municipal fire fighters in the handling of brush and/or forest fires that results from the use of flares during military training exercises. Currently, the groundwater underneath the northern portion of MMR is being considered for development as potable water supplies for the four upper Cape towns of Bourne, Falmouth, Mashpee, and Sandwich. This action plan provides guidance and procedures for conducting fieldwork to gather data and information to determine the effects of military operations on the groundwater beneath the training range and Impact Area.

For more than 40 years, military and law enforcement training has been conducted in the training range and Impact Area at MMR. This training involves three distinct activities:

(i) Small arms firing at several ranges inside the study area, involving the use of small caliber munitions;

(ii) Artillery firing from gun and mortar locations into the Impact Area which is located in the center of the study area; and

(iii) Demolition ranges, one located to the north and just outside the study area; and another to the south of the Impact Area, located within a range inside the study area. The two demolition ranges are used to practice detonation procedures for explosives (see Figure 1-1).

1.3 Objectives of the Investigation

Working cooperatively with federal and state environmental agencies, the local authorities, the Impact Area Citizens Review Team, and the public on the Cape, the Army National Guard (ARNG) is conducting a study of the ground water quality beneath the training range and Impact Area at MMR. This study will determine whether the activities at the training range and Impact Area have affected, or will affect groundwater quality and will include identification of potential source areas of groundwater contamination through soil sampling.

The study will include: a thorough review of the archives to investigate the types and volume of munitions used at MMR and determine the location of potential sources of contamination; the collection of data and information to verify the conceptual groundwater flow model and pattern in the training range and Impact Area; a thorough investigation of suspected potential sources of contamination based on the archives search, interviews, and other means, and by surface and subsurface soil sampling and groundwater monitoring; human health and ecological risk assessments; and evaluation of the quality of groundwater beneath the study area. After a review of the data and as information becomes available, the scope of the investigation may be revised to include and adjust the number and location of investigation wells, conduct potential source investigations and aquifer characterizations to determine the long term effects of military operations on groundwater. The results of these investigations will be used to develop a long term monitoring program and the scope of the policy and/or technical response necessary to protect the quality of groundwater for the long term needs of the population on the Cape.

1.4 Environmental Concerns at the Training Range and Impact area

For more than 40 years, the training range and Impact Area at MMR has been used for military and law enforcement training. These training activities have been widely varied, as well as the size and types of munitions used. The impact of these activities and the fate of the spent

munitions in the environment has been of interest for many parties on the Cape. The training and munitions used by activity and location are as follows:

(a) Small Arms Firing Ranges: These are outdoor pistol and rifle training ranges typically consisting of a firing position, a cleared range area, a target position, and an impact berm. Typically, the weapons that have been fired in these ranges are small caliber weapons including 50 caliber or smaller munitions; with the dominant choice being 5.56, 7.62 and 9 millimeter(mm) small arms rounds. The primary constituent of these munitions is a lead core in a metal alloy jacket, usually composed of copper, iron , and antimony.

(b) Artillery and Mortar Positions: These are small sites in the range area where the artillery and mortars are placed and fired at targets in the Impact Area. In the past, the spent shell casings and propellant bags were disposed of at these locations and/or in the vicinity of the artillery and mortar locations. The munitions used at these sites include 105 mm, 155 mm and 8 inch caliber artillery projectiles and 60 mm, 81 mm, and 4.2 inch mortar cartridges. The chemical constituents of these munitions are similar to those used at small arms ranges but also include explosive compounds.

(c) The Impact Area: This is the centrally located area in the range that contains the targets used for artillery and mortar firing. When the rounds fired are detonated, the explosive materials are generally consumed at the time of detonation. Sunlight degrades most of the remaining explosives. The metal shell casing breaks up into small pieces.

(d) Demolition Areas: These two locations are ranges that are used to practice detonation procedures for explosives. The environmental impacts associated with these ranges may be similar to the target areas in the Impact Area.

(e) Known or suspected unauthorized disposal sites: These include an area that has been identified as "CS-19" and investigated by the IRP, and may include other areas to be identified through archives review, interviews, and by other means.

Explosives are defined as materials which have the potential to chemically change from a solid to a large volume of hot gases very quickly. High explosives (HE) are materials which undergo the chemical change at a rate faster than the speed of sound, such as: TNT (trinitrotoluene), RDX (Cyclonite) , mercury fulminate, and lead azide. Low explosives undergo a chemical change at a slower than the speed of sound and include black powder, smokeless powder and other propellants. TNT has been the most widely used military explosive since World War I. RDX was developed during World War II, and is used in combination with TNT. Mercury fulminate and lead azide are used as primers in ammunition and are unstable.

The primary environmental interests associated with the historic, current and future use of the training range and Impact Area involve the metal projectiles from fired or "spent" munitions. The propellant is designed to be completely destroyed during firing, and while some propellant residues may accumulate at the firing point, the propellant itself is not likely to appear in the Impact Area. In the case of artillery firing, the excess propellant was burned after the firing, also in the immediate vicinity of the firing point. Artillery propellant bags are no longer burned at Camp Edwards. The HE rounds are composed of Composition B explosives, which are a combination of TNT and RDX. The projectile body is composed of forged steel. The explosives in a HE projectile are designed to be destroyed at impact. Since 1985, only metal projectiles, not the live HE artillery rounds have been fired into the Impact Area at MMR for artillery training. Low cost indirect training rounds (LITR) are used in place of HE rounds for artillery training. The LITR rounds are manufactured with a combination of metals (Zinc, Potassium, and Aluminum). There are no explosives used in the artillery projectiles. Subsequently, in March

1997, the Army voluntarily stopped using HE mortar rounds. Currently, only inert short range training mortar rounds, with no high explosive content, are fired at MMR.

The HE in the current munitions used are designed to be completely consumed during firing and upon impact. Therefore, only the metal projectiles end up in the Impact Area. These metals are not very mobile, and numerous studies have shown that they are contained in the first six inches to two feet of the soils.

Other environmental interests, in addition to potential contaminants associated with spent munitions and propellant burning, include any unauthorized disposal activities, use of tear gas or other chemical agents, use of pesticides or herbicides, and release of hazardous materials from equipment used for targets. A comprehensive list of these potential areas for investigation will be completed during the Archives Search phase of this study (see Section 3.1.1).

The investigation will include additional screening analysis to help determine if other military activities in the study area may have effected the quality of groundwater. The archives search will attempt to locate and review records of all activities that may have occurred in the study area in an effort to identify and investigate the use and handling practices for non explosive related hazardous materials (e.g. fuels, solvents, oils). The analytical program includes analyses for nonmunition related constituents.

1.5 Scope of the Action Plan

This action plan presents the technical and investigative aspects of the proposed study of groundwater quality beneath and emanating from the training ranges and Impact Area at MMR as required by the Administrative Order.

The data gathered from this investigation will be used to modify the Pollution Prevention Plan also required by the Administrative Order. The Pollution Prevention Plan will determine the techniques and technologies available to prevent contamination resulting from military training activities.

2.0 BACKGROUND AND ENVIRONMENTAL SETTING

2.1 Site Location and History

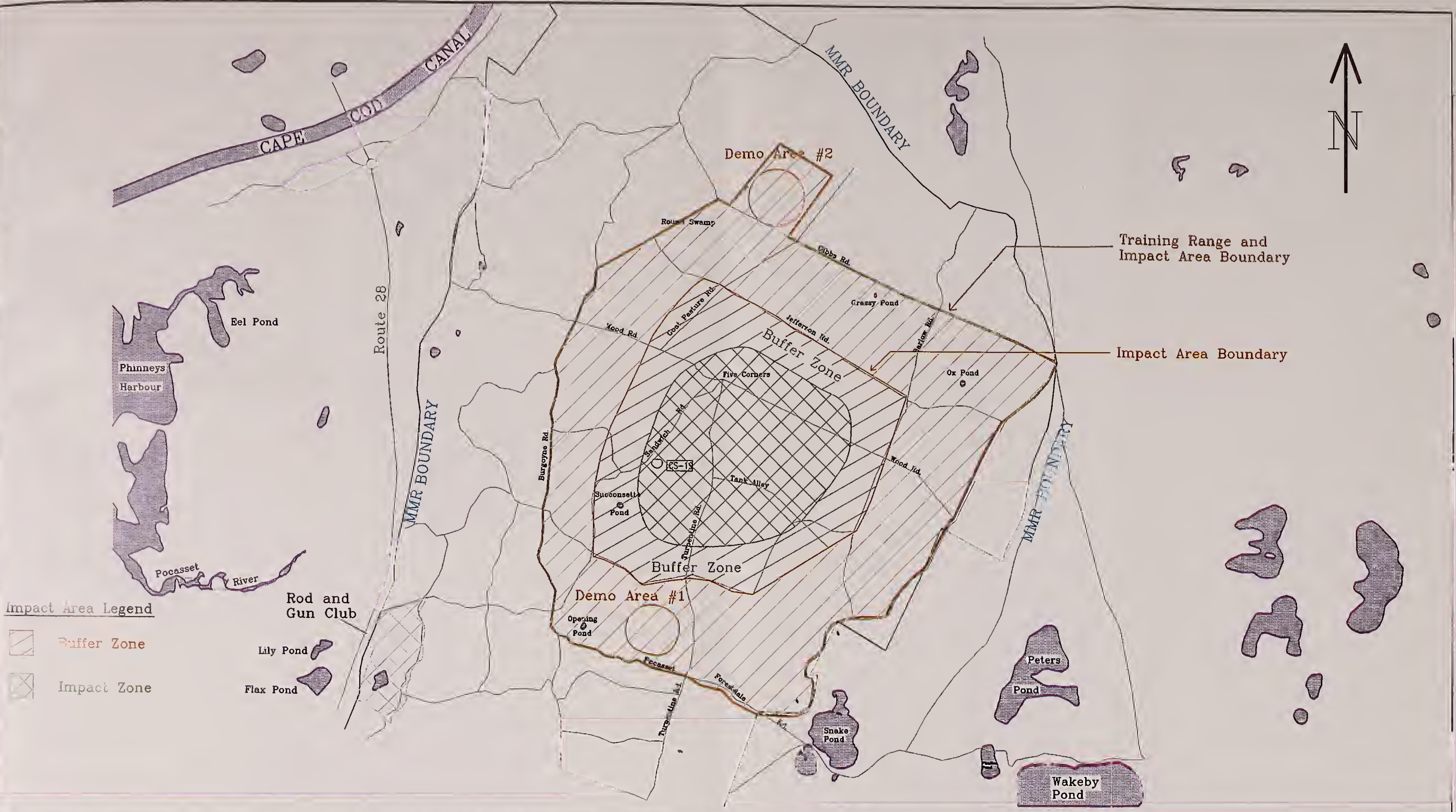
The MMR is located on upper Cape Cod, approximately 60 miles southeast of Boston, Massachusetts (See Figure 1-1). The MMR consists of approximately 21,000 acres. Approximately 14,000 acres, occupying the northern seventy percent of MMR, constitutes the training range and Impact Area (Figure 2-1). The primary focus of this investigation is past, present, and future activities at and in the vicinity of the Training Range and Impact Area. These include the small arms ranges, demolition ranges, artillery and mortar firing positions surrounding the Impact Area, and the Rod and Gun Club to the southwest of the study area (Figure 2-2).

For over 40 years, MMR has been used for military and law enforcement training. This training has included the firing of small arms, guns, hand grenades, artillery, mortar and ordnance demolition. The environmental impacts associated with these activities could potentially affect groundwater.

2.2 Site Description

The Training Range and Impact Area is in the central portion of MMR. Numerous firing ranges, artillery and mortar positions, and training areas surround an Impact Area in the center of the study area (See Figure 2-2).

The Impact Area contains targets at which artillery and mortars are fired during training activities. The primary target area is the strip along the road in the southeast and central portions of the Impact Area referred to as "tank alley." (Tank alley is a row of metal tank hulls used as targets.) The northern portion of the Impact Area around the intersection of Woods, Turpentine



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Source: Analysas, 1995 and US Defense Mapping Topo Maps

MMR IMPACT AREA WORKPLAN

FIGURE 2-1
TRAINING RANGE AND
IMPACT AREA

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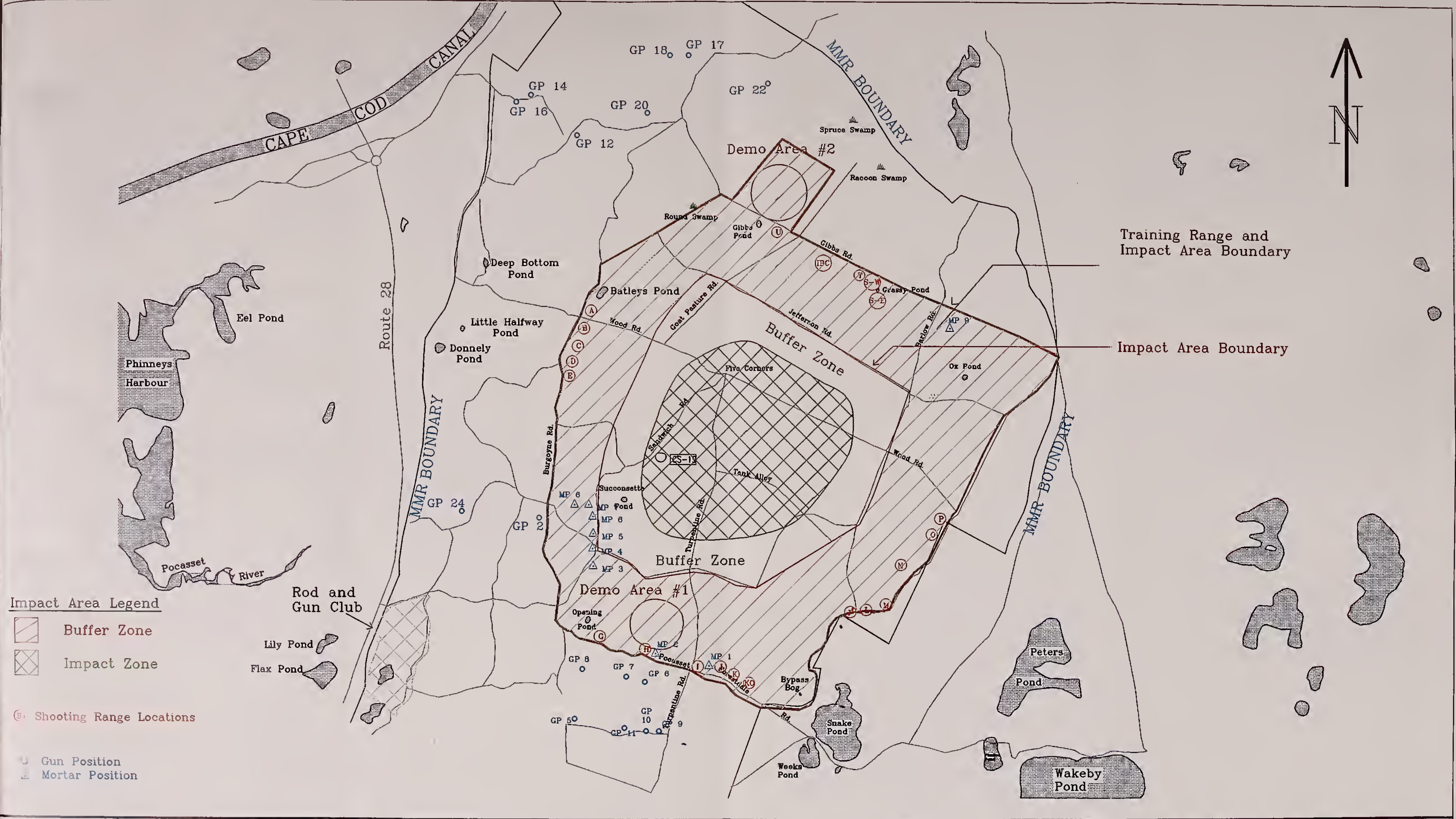

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MMR IMPACT AREA WORKPLAN

FIGURE 2-2
GUN AND MORTAR POSITIONS,
RANGES, AND IMPACT AREA

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and Sandwich roads (also known as the "five corners" area) used to be, but is no longer a target area. The Impact Area includes a 500 meter buffer zone around the target areas (See Figure 2-2). The study area is the area in and near the Training Range and Impact Area.

2.2.1 Physiography and Surface Waters

The Cape Cod peninsula was formed during the retreat of the glaciers at the end of the Ice Age. It consists of two distinct types of terrain resulting from the recession of two separate lobes of ice sheets. The training range and Impact Area are located on a broad, undulating glacial outwash plain with considerably more relief than the area to the south. The elevation generally ranges from 100 to 250 feet with the highest reported elevation of 306 feet above mean sea level (Massachusetts ARNG, 1985). The Impact Area is dotted with natural depressions called "kettle holes". Only one of these kettle holes, Succonsette Pond, which is located in the southwestern corner of the Impact Area buffer zone, contains water (Figure 2-3).

Due to the high permeability of the sands and gravel underlying the training range and Impact Area, there are no perennial streams, and very little to no run-off. This suggests that almost all precipitation in the training range and Impact Area ends up as groundwater recharge or evapotranspiration. The rapid infiltration of rainfall essentially eliminates surface water runoff and ponding - even in most kettle holes. Intermittent streams are only visible in a few drainage swales, and are only active during heavy rainfall. Succonsette Pond appears to be fed from groundwater flow-through, and run-off waters during heavy rainfall events. It has no surface water outflow. Topography of the range shows swales leading out of the Impact Area; others terminate within the range (USGS, 1976).

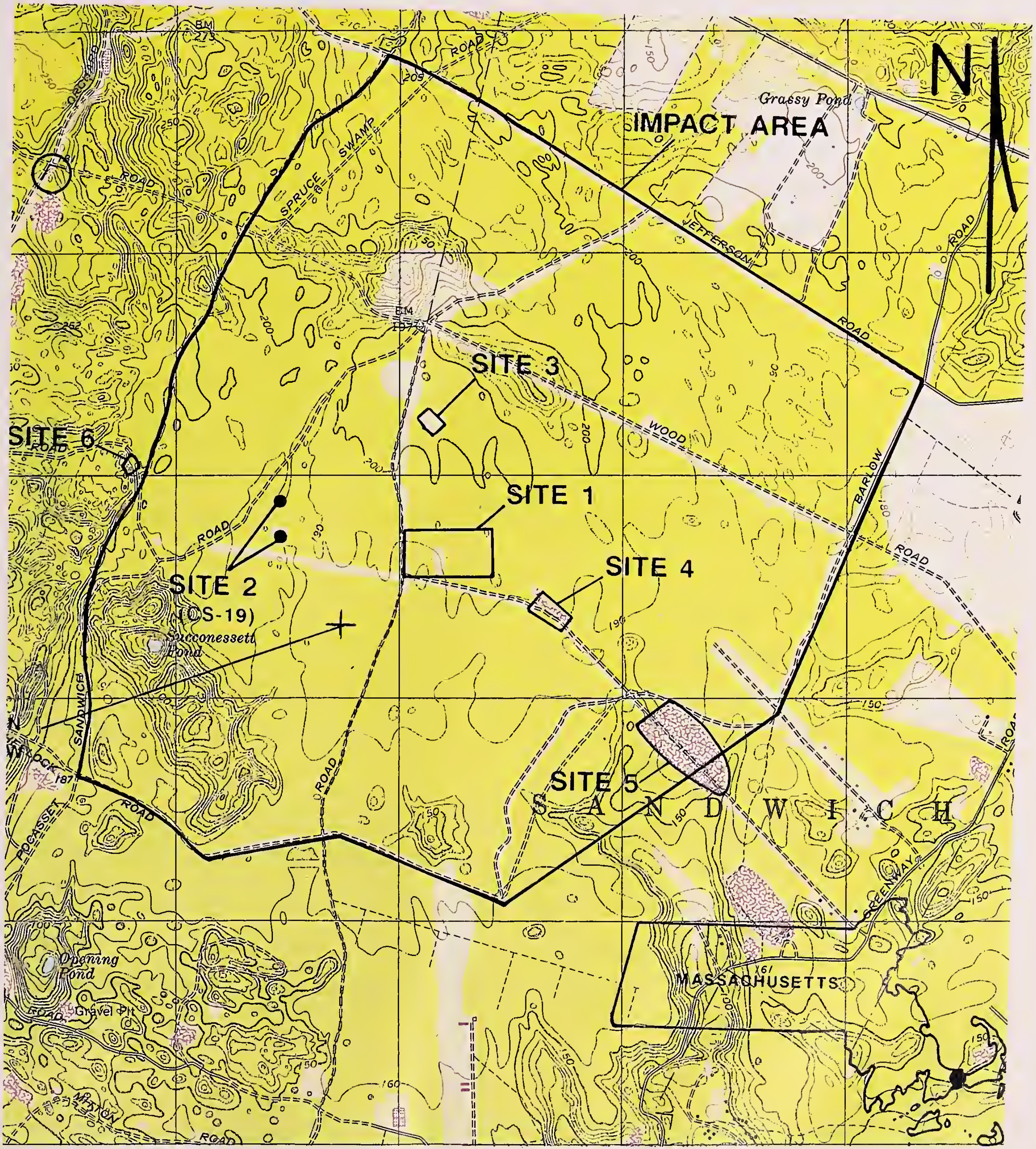

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FIGURE 2-3

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PHYSIOGRAPHIC MAP OF THE
TRAINING RANGE AND IMPACT AREA

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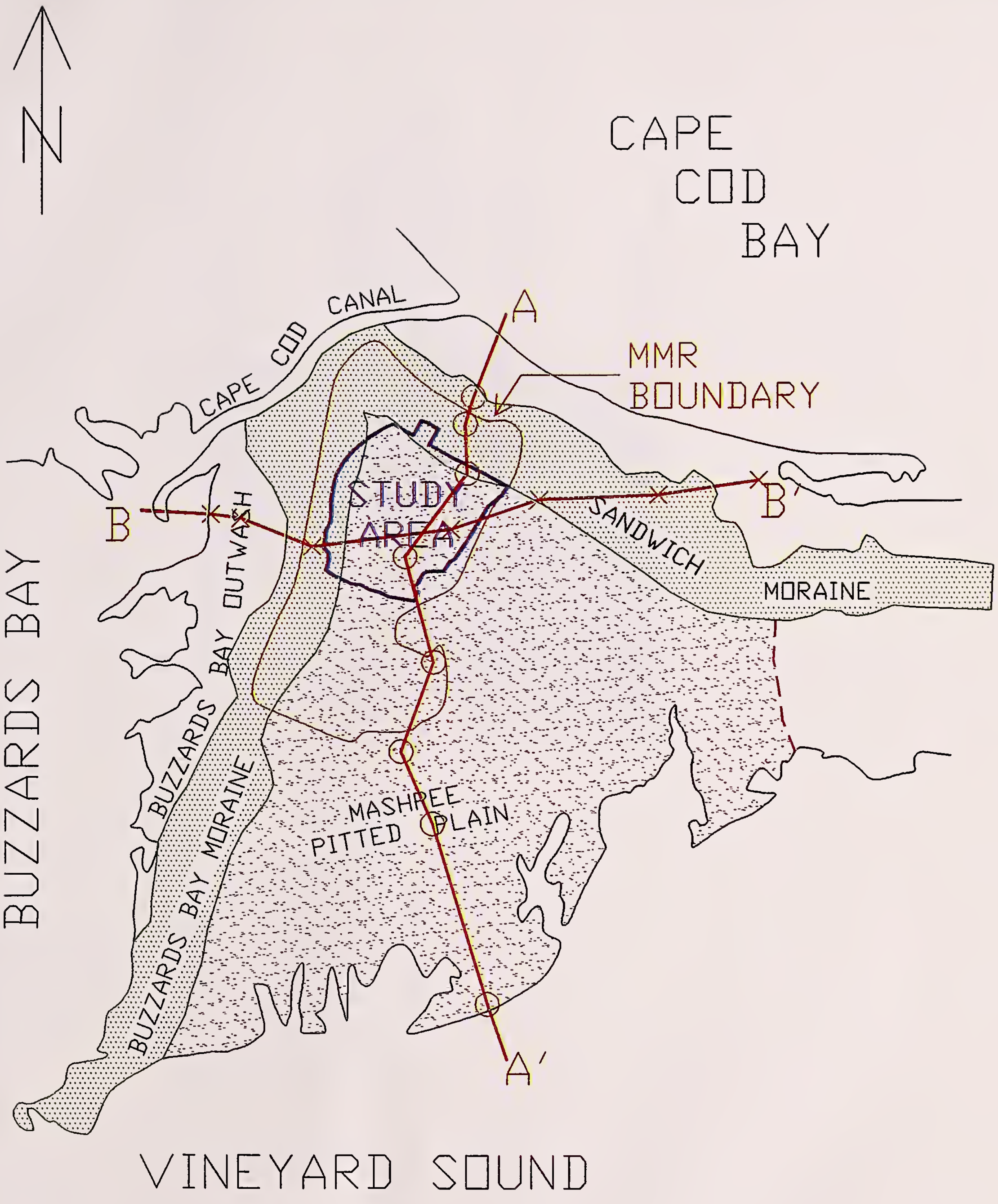
2.2.2 Geology

MMR is located within the Coastal Plain physiographic province. The predominant physical features are moraines and outwash plains composed of poorly sorted, heterogeneous mixtures of sands, silts, gravel, and boulders mixed with well sorted and stratified sands, gravel and silt. These geomorphologic features are a result of depositional processes associated with the advance and retreat of two ice sheets. Three distinct geologic units can be identified: the Sandwich Moraine in the north, the Mashpee Pitted Plain in the southeast, and the Buzzard Bay Moraine in the west (Figure 2-4). The training range and Impact Area is located on the north-central portion of MMR, which is underlain primarily by the Mashpee outwash plain. The geology is comprised of stratified, unconsolidated sands and gravels underlain by crystalline bedrock. Figure 2-5 is a north-south and east-west geologic cross section of the study area as depicted on the USGS Hydrogeologic Framework of Western Cape Cod, 1997. This hydrogeologic framework is based on the depositional history of the sediments of the region. The surface elevations typically vary between 100 and 140 feet above MSL in the outwash plains to about 300 feet above MSL in the moraines. The crystalline bedrock is at an average elevation of 150 feet below MSL (USAEHA, 1986).

The surface and subsurface soils are characterized by a heterogeneous mixture of cobbles, gravel, sand, silt and clay to highly stratified sands and gravel. Typical of these soils are fine loamy topsoil overlying thick sand deposits or silty materials over stratified sand and gravel. All these deposits sit on a bedrock that has been mapped as a granodiorite (USGS, 1976). Radon and the resulting radiation is common in Massachusetts granitic bedrock.



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MMR IMPACT AREA STUDY

FIGURE 2-4
AREA GEOLOGY

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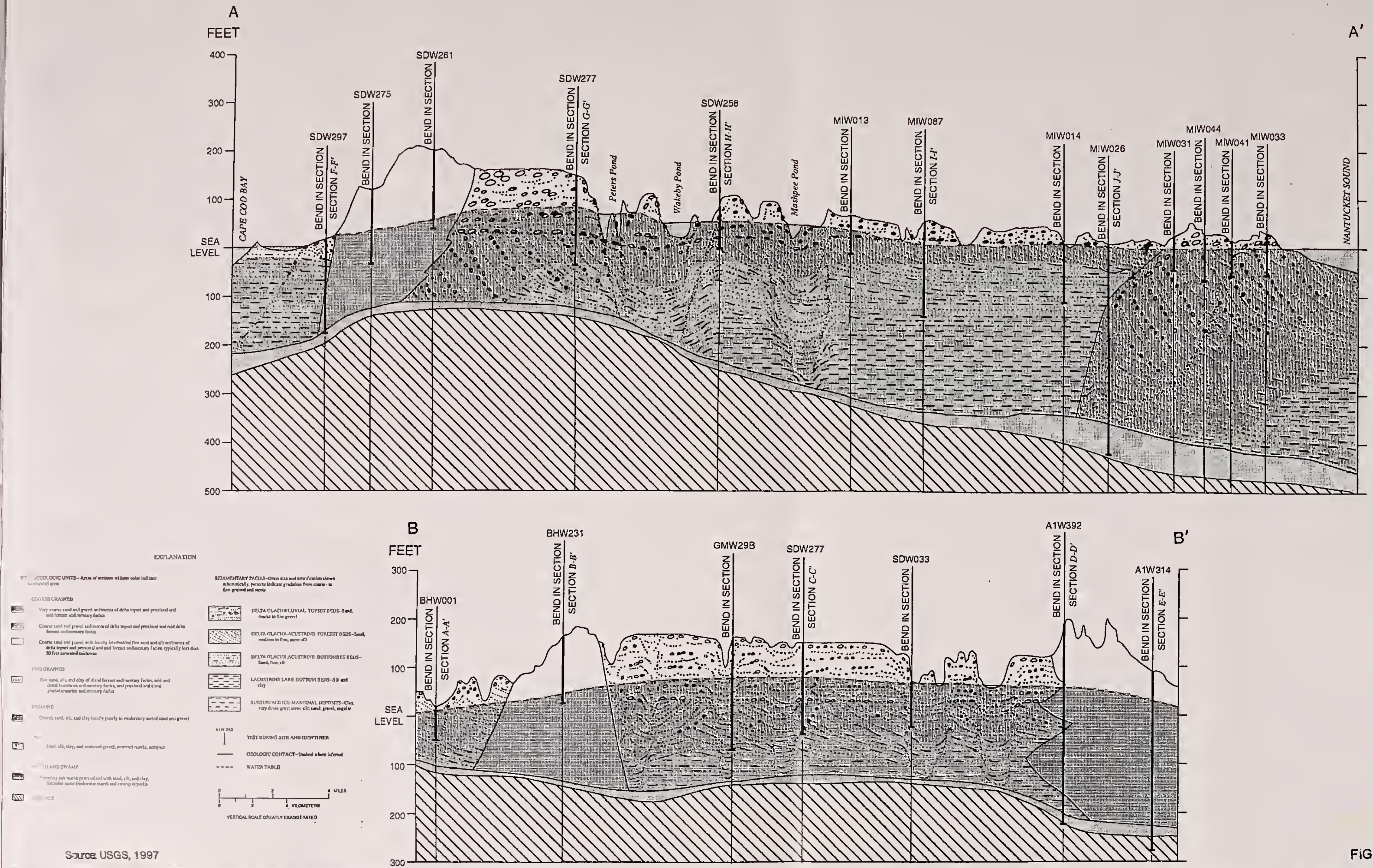
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SDW297
BEND IN SECTION
SECTION F-F′
SDW275
BEND IN SECTION
SDW261
BEND IN SECTION
SDW277
BEND IN SECTION
SECTION G-G′
Peters Pond
Wakeby Pond
SDW258
BEND IN SECTION
SECTION H-H′
Mashpee Pond
MIW013
BEND IN SECTION
MIW087
BEND IN SECTION
SECTION I-I′
MIW014
BEND IN SECTION
MIW026
BEND IN SECTION
SECTION J-J′
MIW031
BEND IN SECTION
MIW044
BEND IN SECTION
MIW041
BEND IN SECTION
MIW033
BEND IN SECTION
NANTUCKET SOUND
B
FEET
300
200
100
SEA LEVEL
100
200
300
B′
BHW001
BEND IN SECTION
SECTION A-A′
BHW231
BEND IN SECTION
SECTION B-B′
GMW29B
BEND IN SECTION
SDW277
BEND IN SECTION
SECTION C-C′
SDW033
BEND IN SECTION
A1W392
BEND IN SECTION
SECTION D-D′
A1W314
BEND IN SECTION
SECTION E-E′
EXPLANATION
HYDROGEOLOGIC UNITS—Areas of sections without color indicate unsaturated zone
COARSE GRAINED
Very coarse sand and gravel sediments of delta topset and proximal and mid foreset sedimentary facies
Coarse sand and gravel sediments of delta topset and proximal and mid delta foreset sedimentary facies
Coarse sand and gravel with locally interbedded fine sand and silt sediments of delta topset and proximal and mid foreset sedimentary facies, typically less than 50 feet saturated thickness
FINE GRAINED
Fine sand, silt, and clay of distal foreset sedimentary facies, mid and distal bottomset sedimentary facies, and proximal and distal glaciolacustrine sedimentary facies
MORAINE
Gravel, sand, silt, and clay locally poorly to moderately sorted sand and gravel
TILL
Sand, silt, clay, and scattered gravel, unsorted matrix, compact
MARSH AND SWAMP
Overlying salt marsh peats mixed with sand, silt, and clay. Includes some freshwater marsh and swamp deposits
BEDROCK
SEDIMENTARY FACIES—Grain size and stratification shown schematically, patterns indicate gradation from coarse- to fine-grained sediments
DELTA GLACIOFLUVIAL TOPSET BEDS—Sand, coarse to fine gravel
DELTA GLACIOLACUSTRINE FORESET BEDS—Sand, medium to fine, some silt
DELTA GLACIOLACUSTRINE BOTTOMSET BEDS—Sand, fine; silt
LACUSTRINE LAKE-BOTTOM BEDS—Silt and clay
SUBSURFACE ICE-MARGINAL DEPOSITS—Clay, very dense gray; some silt; sand; gravel, angular
A1W 263
TEST BORING SITE AND IDENTIFIER
GEOLOGIC CONTACT—Dashed where inferred
WATER TABLE
0
2
4 MILES
0
2
4 KILOMETERS
VERTICAL SCALE GREATLY EXAGGERATED

Source: USGS, 1997

FIGURE 2-5

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DRAWN	AJH 5/97 DATE
CHECKED	MLL 5/97 DATE
APPROVED	DHK 5/97 DATE

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0 1000 2500 5000
SCALE (FEET)

MMR IMPACT AREA WORKPLAN

Geologic Cross Sections
of the Study Area

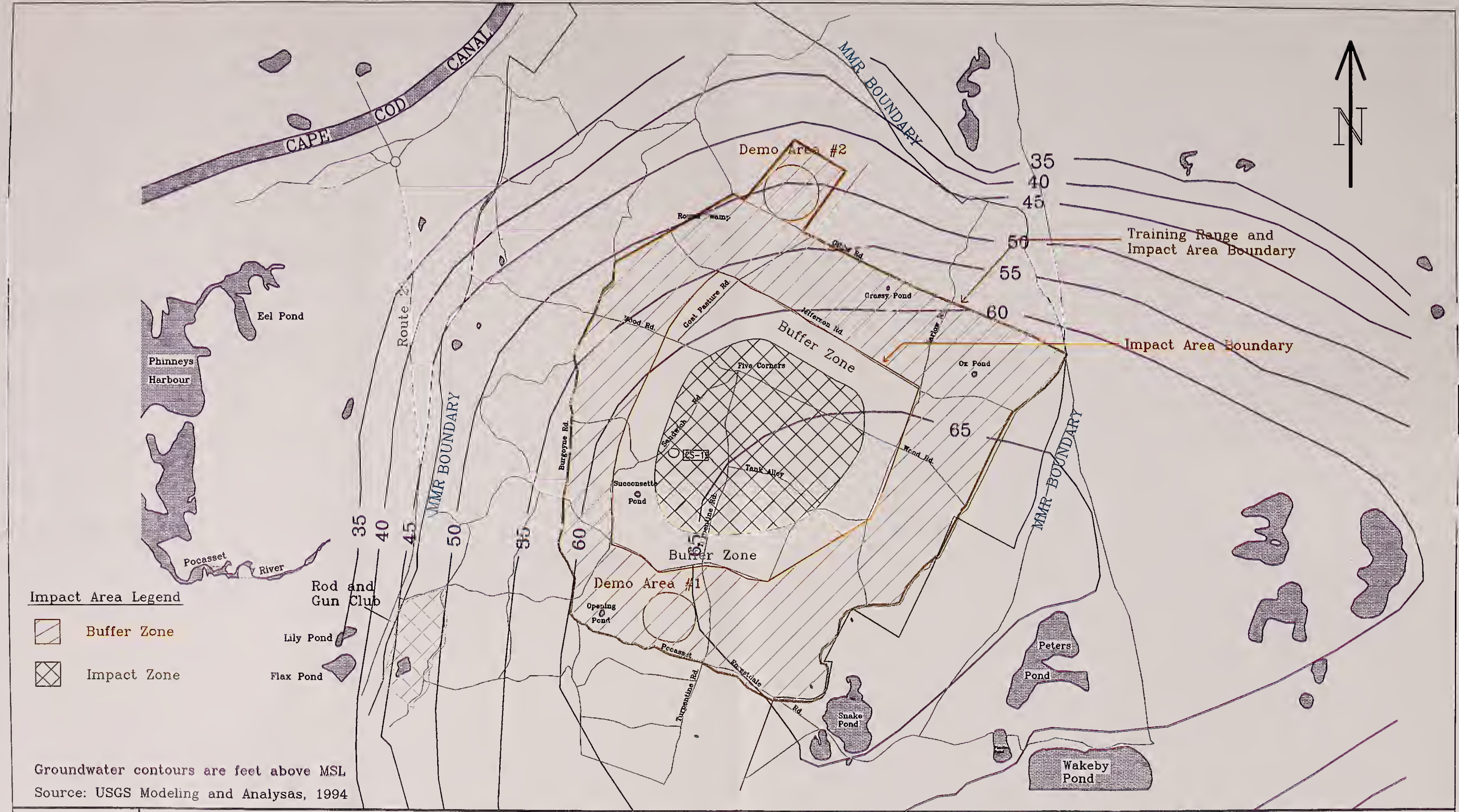
SCALE: | CONTRACT NO.: 97301.10 | DATE: 5/97

2.2.3 Hydrogeology

The aquifer beneath MMR is part of the unconsolidated glacial deposits of Cape Cod, which constitutes the primary and sole source of potable water. The groundwater is under unconfined conditions with the highest groundwater surface elevations beneath the MMR. Therefore, groundwater flows radially in all directions from the Reservation (Figure 2-6).

The training range and Impact Area is a major recharge area. The apex of the groundwater system is southeast of the Impact Zone. The direction of groundwater flow is between west southwest and north northeast.

Recharge to the aquifer is from precipitation, averaging about 21 inches a year. The depth to groundwater can be as deep as 140 feet (ABB, 1992) in areas of high elevations in the training range and Impact Area, and has been documented to be about 115 feet at the IRP CS-19 study area in the Impact Area (USACHPPM, 1996). Based on the predicted water table elevation (see Figure 2-6), the average depth to groundwater in the Impact Zone is 110 feet with less than one percent of the water table within 50 feet of the land surface. The unconsolidated sands and gravels are highly permeable with hydraulic conductivities between 200 and 300 feet per day. With average groundwater gradients of 0.003 percent, the groundwater flow velocity probably ranges between 0.8 to 2.3 feet per day (ft/d) (USGS, 1976). The vertical hydraulic conductivity appears to be relatively high, but lower than the horizontal. Data are limited on this subject, and the extent of anisotropy within the aquifer has not been defined.



Groundwater contours are feet above MSL

Source: USGS Modeling and Analysas, 1994

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0 1000 2500 5000
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Source: Analysas, 1995 and US Defense Mapping Topo Maps

MMR IMPACT AREA WORKPLAN

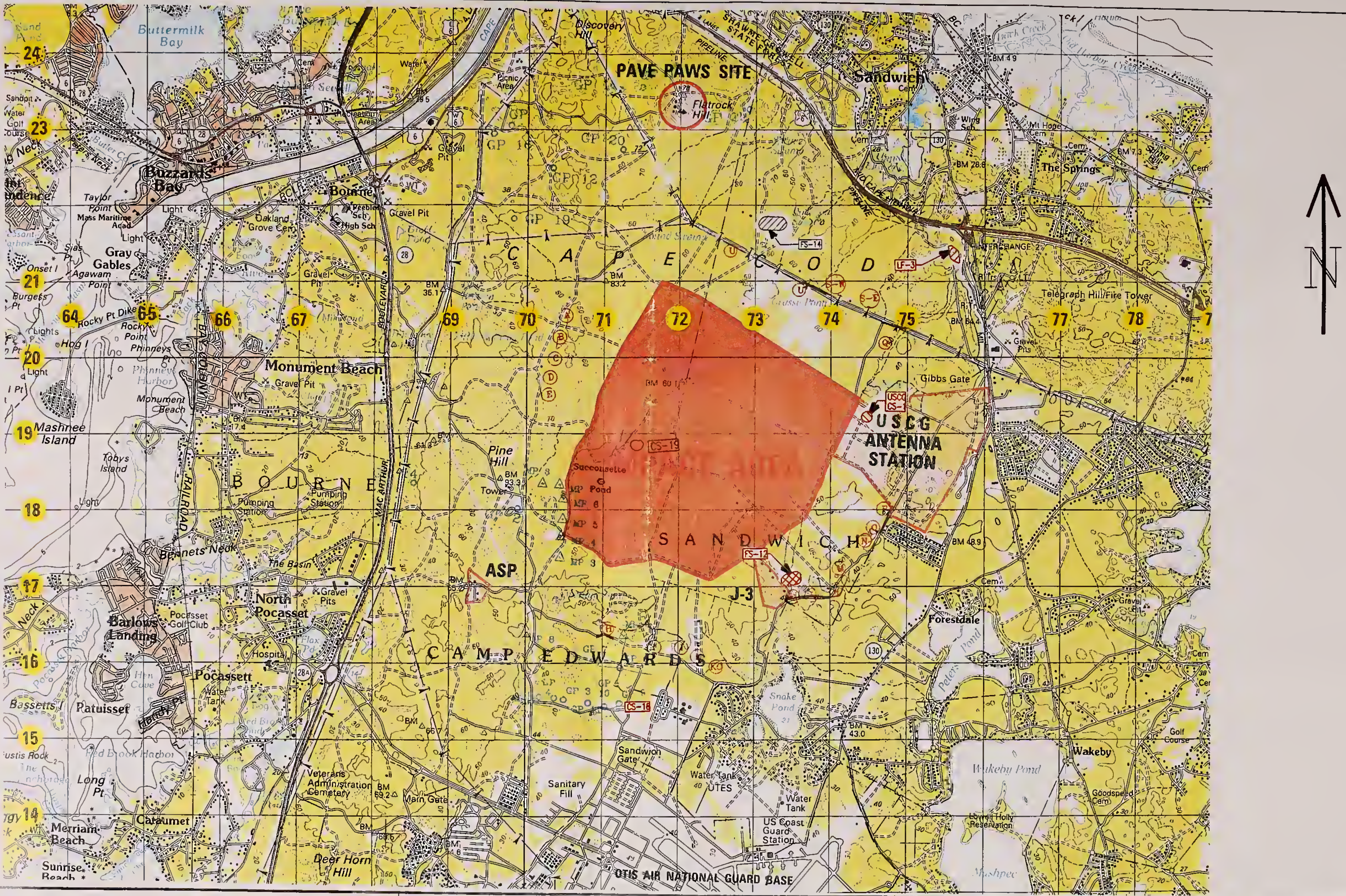
FIGURE 2-6
GROUNDWATER ELEVATION
CONTOURS

SCALE: | CONTRACT NO.: 92307.012 | DATE: 2/97

2.3 Previous Investigations

The study area covers the north-central portion of the installation; and consists of a central Impact Zone surrounded by a buffer zone, and both surrounded by numerous ranges (see Figure 2-2). Small arms training and target shooting are conducted at the ranges, while artillery and mortar fire originate from gun and mortar positions in some of the ranges unto targets located in the Impact Zone. Over the life of the installation, other potential sources (e.g. FS-12, FS-14, CS-1) have been identified in close proximity to the Impact Area (Figure 2-7), and these have been investigated by the IRP. Some of these studies have included the following:

In 1987, the U.S. Army Environmental Hygiene Agency (USAEHA) conducted an investigation of ash remains from the burning of propellant bags at artillery and mortar positions. The scope of this study was limited to determining soil contamination from the ash remains. Two gun positions (GP-8 and GP-9), were selected as representative sites. These sites were investigated as Area of Concern-Chemical Spill -18 (AOC CS-18) under the Installation Restoration Program (IRP). Soil samples were collected from the top 18 inches at burn locations and analyzed for volatile and semi-volatile organics, heavy metals, and explosives. Some of these analytes were detected, but at acceptable levels for the current land use when compared to background levels, except for lead. Due to the fast decline in concentration levels with depth (90% decline within 6 inches of surface), the relative immobility of lead, and the depth to groundwater, the report concluded that the soils were not hazardous, and not an imminent source for environmental concerns. However, the report recommended further investigations. This was due to the lack of specific regulations for contamination from explosives, the potential for change in the regulations, and the limitations of the laboratory techniques available at the time for detecting explosive compounds.



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Ⓑ Shooting Range Locations

○ Gun Position

△ Mortar Position

Source: Defense Mapping Agency, 1988

MMR IMPACT AREA WORKPLAN

Figure 2-7

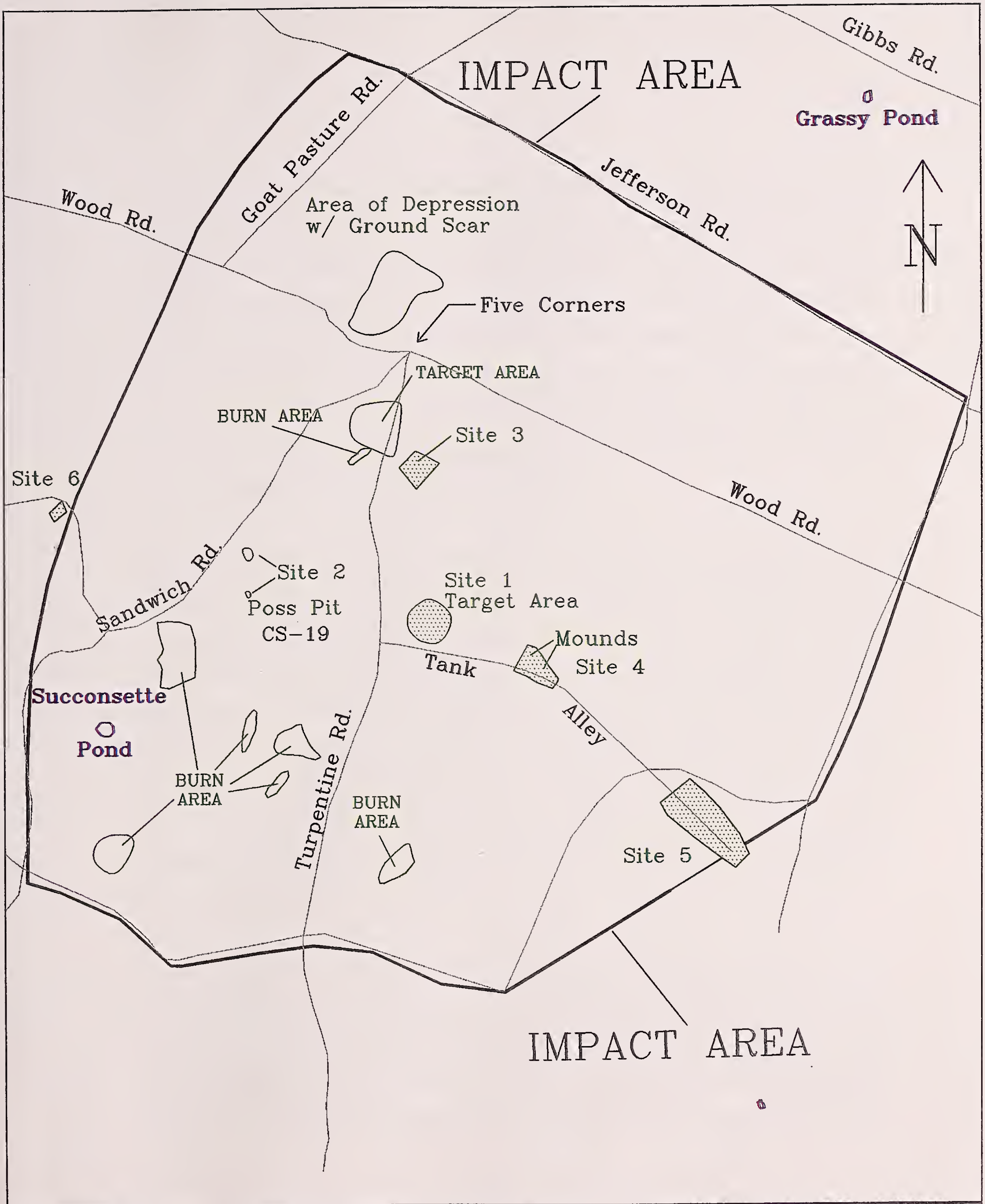
Other Sources in the Study Area

SCALE: | CONTRACT NO.: 92307.012 | DATE: 5/97

In 1994, the U. S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) conducted a follow-on study of the effects of burning propellant bags at two firing positions, GP-8 and GP-9. This study was a detailed investigation of the firing locations, and included soil and groundwater sampling. Soil samples were analyzed for heavy metals, explosives, and semi-volatile organic compounds (SVOCs). Groundwater samples were analyzed for volatile organic compounds (VOCs). The results of this investigation showed some explosives and heavy metals, mostly in the top one foot of soil. A preliminary risk evaluation (PRE) was conducted using these results. The study concluded there was no imminent danger to human health, and no current or expected threat of ecological risk exists from current or continued use of the sites.

Also in 1994, an aerial photographic site analysis (ERI, 1994) was conducted using aerial photographs dating back to 1943. This study covered the whole training range and Impact Area in an effort to identify other sites suspected to be potential sources of past contamination. The analysis was conducted by viewing illuminated transparencies of aerial photos through a stereoscope. Stereoscopic magnification and viewing enables the analyst to identify characteristics associated with different environmental conditions based on color, texture, tone, shape, size and patterns associations. These characteristics allow specific objects and/or conditions to be recognized, and associated with specific activities and sites.

Six sites were clearly identifiable (Figure 2-8), with numerous areas showing varying levels of activity. Some of these areas went through several clearing and revegetation cycles between 1943 and 1991. Several ground scars, which are evidence of burning, were identified over the years, and the primary target areas showed small impact craters throughout the period studied (ERI, 1994). The nature and conditions of these sites are as follows:



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MMR IMPACT AREA STUDY
FIGURE 2–8
AREAS of INTEREST
BASED on AERIAL PHOTOGRAPHS

SCALE:
CONTRACT NO.:
DATE:
SHEET:

1. Site #1 is a circular target area located along Turpentine Road that was first noted in a 1951 photo. It appears to have served as a burning ground with multi-toned, darker soils than the surrounding areas. Piles of materials were noticed on the 1951 photo, but had disappeared by 1958 and the area seemed to have been mechanical cleared. By 1963, the area appears to revegetating. In a 1971 photo, all activities at this location seemed to have stopped. From 1971, the area at Site #1 continued to revegetate until it was no longer distinguishable, except for the shells of old tanks in a row to the south of the site. However, between 1977 and 1991, the area was once again used heavily as an Impact Area judging from the impact craters and the tank shells, presumably used as targets.

2. Site #2 is otherwise known as CS-19 in the IRP Program. This site first appeared in a 1958 photo as a bunker with the area around it cleared; and a small trench was visible to the north of the bunker. A second clearing was located about 600 feet to the south of the bunker at the end of what appeared to be a new access road. Through the years until 1963, the bunker and clearing were visible, but the trench did not exist in a 1963 photo. No changes were observed in the conditions of the site until 1977 when three new pits were noticed in the northern area. These pits had liquid in them. A review of hydrologic data for the week preceding the photo indicated that 3.39 inches of rainfall was recorded that week. These two sites were still visible in a 1991 photo, with what appears to be a pit located at the entrance to the access road.

3. Site #3 is another target area which was first noticed in 1951 as a ground scar and topographic depression, but developed into a second Impact Area which seemed to have become active about the same time (1958) as Site #1. New ground scaring and impact craters were visible to the north and south of the five corners area bothering the topographic depression. In addition, numerous fires were burning at this time (April 30, 1958) to the

south of the area. By 1963, the target area had shifted first to the south of Five Corners and then to a new area to the east of Turpentine Road and about 1800 feet south, southeast of Five Corners. This new target area had three trenches along the borders of the target, two antenna in the center and a viewing towers at the northeast boundary. The area appeared to be revegetating in a 1965 photo, but the trenches were still in place. This target area appears to have been used throughout its existence, up till the present. There seem to have been some earth-moving work done at the site in 1985, and the unvegetated areas are still unvegetated.

4. Site #4 first appeared in a 1963 photo, and consisted of a pile of soil and rubble. This pile appeared to be associated with, and is part of the construction of "J" Range located to the Southeast. This pile has existed since then, and continues to grow as more rubble (including old armored vehicles) is added to the pile. In 1970, a new access road was constructed from the pile to the target area (site #1) and armored vehicle shells placed along the road. In 1971, a topographic depression which contained water, was observed near the pile. A review of rainfall data indicated a total of 1.42 inches of rain in the previous week. The mound of dirt and rubble was still visible in 1977, but no standing water or depression was visible. The armored vehicle shells are in the same locations. By 1991, a second mound is visible on site and both mounds appear to have been used to store dirt used to construct the backstop for the "J" Range.

5. Site #5 is the "J" Range; also known as the Textron Site. This range existed before 1966 when it was enlarged and first appeared in an air photo. A new portion was under construction in 1970 and a large area was cleared. In 1971, two trenches were clearly visible in the northwestern portion of the site, and the site was dotted by earth moving equipment. Over the next few years, numerous trenches were dug for backstop materials

until 1977 when all but one of the trenches was visible. The mounds of dirt and a partially filled trench are still present. The cleared area is also much longer than in the 1975/1976 photo. By 1985 and certainly by 1991, all the old trenches and debris are gone from the site. A new trench is present in the southeastern end of the range; with a pile of dirt at the northern end of the trench.

6. Site #6, a vehicle and supplies staging area, first appeared in a 1970 photo as a cleared and disturbed area adjacent to the western boundary of the Impact Area on Monument Beach Road. This site seems to have been cleared and graded as a storage area for bulk supplies and support vehicles. This area seems to have been used between 1970 and 1985. By 1991, the use of the site had been suspended, and the area seems to be revegetating.

In addition to these six sites, there are five other areas in close proximity to the site; including the FS-12, FS-14, USGS-CS-1, CS-18 and LF-3 sites which have all been investigated by the IRP. The following are a brief summary of the findings, and the current status of these sites.

1. The FS-12 site is a known jet fuel spill site dating back to the early 1970s. The site has been investigated and is currently being remediated under the IRP. The site is located near the apex of the groundwater recharge area.

2. FS-14 is an IRP site located to the north of the study area. It was the site of a 500-gallon gasoline spill in 1985. Contaminated soils were excavated and removed from the site the very next day. In 1992, the site was identified in a Preliminary Assessment (PA), and a Site Inspection (SI) conducted in 1996. This SI consisted of soils and groundwater sampling and analysis. No gasoline components were detected in any of the samples collected and

therefore, a no further action decision is being required of the EPA by the IRP. FS-14 is downgradient of the study area.

3. USCG-CS-1 was a suspected solvent spill area consisting of several smaller sites including a former drummed hazardous waste storage area in the transmitting building, a buried fuel line, a 4,000-gallon above ground fuel storage tank, a storage building, an illegal dump site to the east of the transmitting building, and a magnetic anomaly to the west of the transmitting building. Review of historical documents indicated that small amounts of solvents were disposed of at scattered locations around the transmitter building. The SI and RI conducted at the site did not identify any hazardous contaminants, but did detect compounds associated with normal lawn maintenance. The concentrations of most of the compounds detected, including PCB, xylenes, PAHs, Chromium, Lead and Mercury were estimated, and were detected below the detection limits. Shallow groundwater samples collected from seven wells contained trace amounts of TCE, 1,1,1-TCA, and chloroform; and these levels were not traced to any particular source. Deeper groundwater monitoring via annual sampling (20 feet below water table) and analysis has provided results showing all contaminant levels to be below MCLs. Monitoring stopped in 1993 with a record of decision document to the EPA.

4. CS-18 is also known as Gun Position-9 (GP-9) which was investigated as a worse case representatives of all the gun positions based on the volume and frequency of use. The investigation included soils and groundwater sampling and analysis. Soil samples were collected from surface to the water table, and monitoring wells installed and sampled. Results indicate that soil contamination from explosives is limited to the top 18 inches of soil, and that the groundwater has not been affected by the activities at this site.

5. LF-3, located on the northeastern boundary of the MMR and to the northeast of the Impact Area, was a one time incident when somebody illegal dumped household materials including old furniture and construction debris. Upon discovery in 1995, the junk was removed and properly disposed of at the main base landfill (LF-1). The site was closed under the IRP program.

Under the IRP, a site investigation was conducted at the CS-19 location, identified as site #2 in the ERI study, within the Impact Area in 1992. This investigation included personnel interviews, geophysical surveys, and soil sampling. Soil samples were collected and analyzed for heavy metals, VOCs, SVOCs, herbicides, and polychlorinated biphenyls (PCBs). The geophysical surveys indicated that nearly all the identifiable anomalies were attributable to surface or subsurface metallic debris. The results of the laboratory analysis of soil samples indicated the presence of several organic and inorganic chemicals. The organics included one explosive compound, HMX (Cyclotetramethylene-tetranitramine), some pesticides including endrin ketone, alpha-BHC, heptachlor, 4,4-dichloro-diphenyldichloroethylene (DDE) and 4,4-dichlorodiphenyldichloroethane (DDD), endosulfan sulfate; some herbicides, dioxins, and furans. Inorganic chemicals detected included aluminum, chromium, copper, iron, lead, magnesium, manganese, mercury, vanadium, nickel, arsenic, barium, beryllium, cadmium, calcium, potassium, silver and zinc. Most of these compounds were detected in samples taken from surface to 3 feet deep. Based on the operational history, as narrated through interviews with past and present personnel, the levels of contamination detected and the behavior of these chemicals in the environment, the report concluded that groundwater contamination from this site is not likely (ABB, 1992).

As a follow-up to the 1992 study, four groundwater monitoring wells were installed at CS-19 to assess the effect of the site on groundwater. Analysis of samples from these wells indicated the presence of RDX (Cyclonite, an explosive compound) in two of the wells screened at about 110

to 120 feet below surface, suggesting that explosive chemicals had reached the groundwater table. The detection of RDX in the groundwater at CS-19 is suspected to be from past disposal practices(USACHPPM, 1994). The presence of RDX in groundwater also has precipitated a supplemental investigation by the IRP at CS-19.

The U.S. Army Engineers Waterways Experiment Station in Vicksburg, Mississippi has investigated the vertical migration potential of heavy metals at small arms ranges at MMR (Bricka, 1996-Draft Report). Soil samples were collected from borings varying in depth from surface to 90 feet, and analyzed using EPA methods SW-846. The potential for vertical migration was estimated using the one-dimensional advection-dispersion equation for non reactive, dissolved constituents. The predicted downward migration of metals in soils from historical small arms use occurs at an average rate of approximately 2 to 3 inches per year. Within the top 21 inches of soil, the predicted rate is 0.6 inches per year. This figure is conservative, considering the low clay and organic matter content of the soils at MMR. Furthermore, the advection-dispersion equation assumes saturated, homogeneous and isotropic materials under uniform flow. Based on the results of this investigation, it seems that the conditions for vertical migration at the site are considerably more favorable than those at locations with more silty/clayey geological environments. These results are preliminary and approximate. Data gathered during this investigation will be used to refine the estimates of metal migration characteristics during the risk assessment.

2.4 Site Conceptual Model

This section will present a conceptual model of the Impact Area and its environs. The conceptual model is a qualitative description of the site hydrogeology as well as the fate and transport of munitions-related materials. In the Action Plan, the site conceptual model helps to define the appropriate investigation activities by outlining the environmental processes that affect the distribution, movement, and persistence of munitions-related materials. The current conceptual model is based on data on the regional hydrogeology, historic practice at the site, and

observations of the behavior of munitions-related materials at other locations. This information is summarized in the proceeding subsections. As site-specific data become available, the site conceptual model will be refined. It is anticipated that groundwater modeling will be used to supplement the conceptual model. The Completion of Work Report will contain an updated version of the site conceptual model.

2.4.1 Site Hydrogeology

This subsection will present a brief discussion of the hydrogeology of the Impact Area and the surrounding region. This will include a discussion of the lithology, the observed water table, and inferred groundwater flow directions. Much of this material is derived from reports based on joint studies between the US Geological Survey and the National Guard Bureau.

The hydrogeology of western Cape Cod is strongly affected by the glacially-deposited aquifer materials (Masterson et al., 1997). The surficial sediments of the Impact Area and the surrounding region are comprised of four distinct units:

- The Mashpee Pitted Plain. This deposit consists of relatively coarse grained materials and extends from a point approximately 2 miles from the Cape Cod Canal south and east to Nantucket Sound. The unit was formed as a delta. The surficial sediments consist of sands and gravels. The deeper deposits are generally finer consisting of medium to fine sand with small amounts of silt. The lowest unit is glaciolacustrine (glacial lake sediments) in origin and consists of layered fine sand and silt. The estimated hydraulic conductivity of these units generally decline with the increased fine fraction and with depth. The ratio of horizontal to vertical conductivity (anisotropy) changes with the increase in finer material. Thus, the surficial sediments are estimated to have a horizontal hydraulic conductivity of 350 ft/day and the ratio of horizontal to vertical conductivity is estimated to be 3:1 (Masterson et al., 1997). For the deeper

sediments, Masterson et al. (1997) estimated a horizontal conductivity of 30 ft/day and an anisotropy of 100:1.

- The Buzzards Bay Moraine. This unit is located near the western margin of Cape Cod and runs approximately parallel to the western coast. The Buzzards Bay Moraine is approximately one to two miles wide (east to west) and has very complex lithologic characteristics. The moraine has been observed to have numerous discontinuous lenses of fine-grained materials. While the hydrogeologic characteristics of the moraine deposits are believed to be less suitable for water supply (i.e., estimated hydraulic conductivity of 10 to 150 ft/day and wide variation in hydraulic characteristics - Masterson et al., 1997), the hydrogeology of the moraine is generally less well understood than that of the Mashpee Pitted Plain.
- The Sandwich Moraine. The Sandwich Moraine is very similar to the Buzzards Bay Moraine in hydrogeologic characteristics. Masterson et al. (1997) describe the two units together and apparently find few distinguishing characteristics. The Sandwich Moraine Runs approximately parallel to Cape Cod Bay and is approximately one to two miles in width (north to south).
- The Buzzards Bay Outwash Deposits. These surficial deposits lie to the west of the Buzzards Bay Moraine and are apparently similar in nature to the deltaic deposits of the Mashpee Pitted Plain (i.e., a productive unit that is increasingly fine grained with depth).

Masterson et al. (1997) believes that all of these surficial units are underlain by lake-bottom beds of silt and clay. This unit is generally believed to be directly above the bedrock with an approximate thickness of 10 to 80 feet. The hydraulic conductivity of this unit is estimated to be 10 ft/day and the ratio of horizontal to vertical conductivity is estimated to be 100:1.

While the precise boundaries to each of the hydrogeological units are uncertain and there may be some degree of overlap with depth, the Impact Area apparently lies largely on the Mashpee Pitted Plain surficial unit (see Figure 2-4). The two moraines lie at the western and northern edge of the Impact Area. Thus, activities ancillary to the Impact Area (e.g., some gun positions) lie on moraine deposits. Given the water table configuration depicted by Masterson et al. (1996 and 1997), groundwater flow from the Impact Area is likely to include flow through the moraine deposits.

The aquifer present in western Cape Cod is generally an unconfined one. The water table surface (see Figure 2-5 and Masterson et al., 1997) exhibits a high point (elevation of approximately 65 feet above sea level) that incorporates the southeast portion of the Impact Area and extends to the south and east. The water table slopes away from the high point in all directions at approximately equal gradients. Based on this water table, groundwater flow from the majority of the Impact Area will likely be to the north and west. At the eastern and southern portions of the study area, groundwater flow is to the east and south (FS-12 site).

It should be noted that while the general direction of groundwater flow can be hypothesized based on the groundwater contours, the precise path a potential plume would follow is more difficult to estimate. In particular, as pointed out by Masterson et al. (1996), plumes observed in other portions of the MMR are relatively narrow and are deflected horizontally and vertically by changes in the hydraulic conductivity of the aquifer materials.

Groundwater production wells are being developed around the edges of the Impact Area at a distance of approximately two to three miles. These wells are not currently in production. As they are brought into production, they have the potential to affect the groundwater flow patterns beneath the Impact Area.

The unsaturated zone beneath the Impact Area is very extensive. Masterson et al. (1997) presents cross-sections that indicate an unsaturated thickness ranging from 100 feet to in excess

of 200 feet in the vicinity of the Impact Area. Borings completed at CS-19 indicated a water table at approximately 115 feet below ground surface.

Given the nature of the surficial materials at the Impact Area, infiltration through the unsaturated zone is expected to be relatively rapid. As noted in Section 2.2, the rate of aquifer recharge has been estimated at 21 inches per year. A downward vertical gradient is expected in the Impact Area groundwater.

2.4.2 Fate and Transport of Munitions-Related Materials

When considering the fate and transport of chemicals in the environment, it is important to consider the nature of the environment (as described above) as well as the physical-chemical properties of the chemicals and their means of introduction into the environment. Impact on ground water from munitions will be dependent on the physical and chemical characteristics of these compounds and their mobility in the subsurface environment. There are two classes of compounds that may reasonably be anticipated from munitions. The first is explosive compounds. There is a growing body of literature that addresses the environmental fate and transport of explosives (McCormick, Cornell and Kaplan, 1981; Kaplan, 1982; Leggett, 1985; Pennington and Patrick, 1990; Ainsworth et al, 1993; McGarth, 1996; Townsend and Meyers, 1996, Brannon and Myers, 1997). Explosives are subject to degradation and sorption in the subsurface environment. The second class of compounds are metals. Metals do not degrade since they are elements, but they are subject to chemical reactions and sorption.

2.4.2.1 Explosive Compounds

The literature on the environmental fate and mobility of explosive compounds focuses on TNT, RDX, and HMX. These were widely used high energy explosives and have been found in the environment at other sites.

2.4.2.1.1 TNT

2,4,6-trinitrotoluene (TNT) is a crystalline solid at room temperature. It is slightly soluble in water with a solubility of 130 mg/l (Urbanski, 1964 cited in McGrath, 1996).

TNT degrades both abiotically and as a microbiologically mediated reaction (Townsend and Meyers, 1996). Microbiogically mediated degradation is typically faster than abiotic and the reaction proceeds fastest under anaerobic (oxygen free) conditions (Townsend and Meyers, 1996). The principal degradation products are 2-amino-4,6-dinitrotoluene (2A-DNT), 4-amino-2,4-dinitrotoluene (4A-DNT) and 2,6-diamino-4-dinitrotoluene (2,6-DANT). There is evidence that these degradation products are also toxic (Honeycutt et al, 1996). Complete mineralization of TNT has been documented through cometabolism (TNT was not the only source of carbon for the microorganisms) under aerobic conditions (Gunnison et al, 1993).

Volatilization is not an important environmental process for TNT. TNT exposed to sunlight degrades via photolysis (McGrath, 1996).

Sorption is an important process affecting the mobility of TNT. Partition coefficients have been derived for a variety of surface soils although many of these studies failed to account for transformations of TNT during the experiments (Townsend and Meyers, 1996). Partition coefficients (sorption) are higher for clay and silt than sand. Although some investigators have found a correlation between organic carbon content and TNT sorption, the primary sorption mechanism is sorption on inorganic surfaces (Pennington and Patrick, 1990).

2.4.2.1.2 RDX and HMX

Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX or cyclonite) is a crystalline solid at room temperature. It is slightly soluble in water with a solubility of 42 mg/l (Sikka et al, 1980 cited in McGrath, 1996). Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetraazocine (HMX) is a crystalline solid at room temperature. It is virtually insoluble; its solubility is 2.6 mg/l (Spanggord, 1982 cited in McGrath, 1996).

RDX and HMX degradation takes place only under anaerobic conditions. Although several investigators have noticed degradation of RDX and HMX under aerobic conditions, it only occurs in clay and silt soils where there may be microanaerobic zones where anaerobic degradation occurs. It is suspected that RDX and HMX degradation are microbiologically mediated processes. The degradation products of RDX and HMX are not known because of the lack of analytical protocols for these compounds (Townsend and Meyers, 1996).

Volatilization is not an important environmental process for RDX and HMX. RDX and HMX exposed to sunlight degrade via photolysis (McGrath, 1996).

Sorption is an important process affecting the mobility of RDX and HMX. Partition coefficients have been derived for a variety of surface soils (Townsend and Meyers, 1996). RDX is slightly less sorptive than HMX which in turn is less sorptive than TNT. The impact of organic carbon content on sorption is unknown, although partition coefficients (sorption) are higher for clay and silt than sand indicating that sorption to inorganic surfaces dominates.

2.4.2.1.3 Other Explosive Compounds

Other explosive compounds include N,2,4,6-tetranitro-N-methylaniline (tetryl), pentaerythritol tetranitrate (PETN), and ammonium picrate. Information on the environmental fate and effects of these compounds is limited. Their use in munitions was limited compared to TNT, RDX, and HMX. Environmental testing includes compounds such as 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitroluene (2,6-DNT) and 1,3,5-trinitrobenzene (TNB). These compounds are not used as explosives; they are byproducts of TNT manufacture and are typically found with TNT. They have been found at sites where contamination of the environment with TNT occurred.

2.4.2.2 Metals

The metals related to munitions are antimony (Sb), arsenic (As), barium (Ba), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), and zinc (Zn). Antimony, As, Ba, Cu, Pb, Hg, and Zn are known

as heavy metals. They normally only occur in trace amounts in uncontaminated aquifers. They have somewhat similar fate and transport properties. Their occurrence in ground water will be controlled by the oxidation state of ground water (generally the oxygen content), solubility and sorption onto inorganic surfaces. In the absence of reducing (no oxygen) conditions, these heavy metals are immobile in ground water. They exist in the subsurface adsorbed to iron and manganese hydroxides (Jacobs, 1997). Uncontaminated ground water at MMR is generally expected to be oxidizing, slightly acidic, and low in total dissolved solids, so that heavy metals would be immobile. If there are reducing zones in the aquifer, heavy metals, if present, would be mobile. The recent investigation of inorganics in MMR ground water found that there were no sites with heavy metal contamination of ground water. All of the plumes that had elevated heavy metal concentrations could be explained by reducing conditions in the aquifer that allowed heavy metals to go into solution, or ground water samples had entrained suspended solids with sorbed heavy metals. (Jacobs, 1997).

The remaining metal related to munitions is Fe. Iron is ubiquitous in the Sagamore lens aquifer. Under normal aquifer geochemical conditions, aerobic and slightly acidic dissolved iron concentrations are extremely low (< 100 micrograms/liter) (Jacobs, 1997). The subsurface iron exists as ferric hydroxide, which is insoluble. In the absence of organics in ground water causing reducing conditions, Fe will be immobile in the subsurface.

2.4.2.3 Distribution of Munition-related materials to the Environment

Materials derived from munitions were deposited through two broad classes of activities: practice firing into the Impact Area and activities associated with disposal of munitions, propellants, etc. Practice firing is likely to result in projectile materials being introduced into a relatively broad area (e.g., several hundred feet around a target) but the materials (e.g., munitions fragments and/or unexploded ordnance) are likely to be distributed in a very heterogeneous fashion within that area (Jenkins et al., 1996). Projectile materials are not expected to be found at great depth.

Unexploded explosive materials tend to retain their crystalline structure in the environment and to leach dissolved organics at a low rate (Jenkins, 1997). Metal fragments would be expected to behave in a similar fashion. Therefore, a reasonable description of the projectile remnants is that each fragment acts as a localized, relatively low-grade source of its component materials. Evaluation of the potential impact to groundwater quality should consider the integration of these individual sources over the area(s) affected.

Practice firing may also result in the introduction of propellant materials into soils in the vicinity of the gun position. Such materials are likely to result from deposition of particles in air suspension and, therefore, are likely to be found relatively uniformly distributed in surface soils around the gun positions.

Materials disposal is likely to have taken three different forms: simple disposal onto the soil surface, burning of materials (e.g., propellant bags), and “wash-out” of propellant using water followed by disposal of the water on the ground. The first two of these activities is likely to result in relatively localized, uniform distribution of materials in soils. Wash-out activities have the potential to introduce materials in suspension and/or in solution deep into the unsaturated zone due to the rapid movement of the wash water through the soils.

2.4.2.4 Fate and Transport Summary

The following conclusions are based on the literature review of the fate and transport of munition-related materials in the environment and consideration of the MMR site conditions.

- The persistence and mobility of explosive materials is relatively complex and is likely to vary substantially with site conditions. For compounds such as TNT, transformation is likely to be an important process. Sorption to soil and aquifer solids is also likely to be important but is not necessarily correlated with soil organic carbon content (Jenkins, 1997). RDX is generally less sorptive and apparently undergoes more complete mineralization than does TNT.

- While both TNT and RDX are relatively poorly water soluble, both compounds are polar. Their poor water solubility derives from their high stability in crystal form rather than non-polar interactions with water. This helps to explain why these explosives are relatively stable in soils yet can have relatively high mobility in groundwater once they are in solution (Jenkins, 1997).
- Metals are affected by reactions with solid surfaces and other ions in water solution (i.e., sorption and precipitation, respectively). While metals are persistent, they may have very high affinity for solids and therefore move very slowly in groundwater. Increased mobility of metals is generally associated with low oxidation-reduction potentials which, in turn, is often associated with high concentrations of degradable organic compounds.

2.4.3 Summary of the Conceptual Model

The following conceptual model will be organized along the potential migration pathway of munitions-derived materials to groundwater. The elements of the potential migration pathway are: (1) deposited materials subject to leaching in surface and shallow subsurface soils; (2) migration of materials through the unsaturated zone with infiltrating precipitation; and (3) migration of materials in groundwater. Each of these potential steps will be defined to the extent possible based on the available data. If major uncertainties exist around a process, this will be highlighted.

The munitions-related materials in and around the Impact Area are most likely to be found in surface soils. This is consistent with the majority of site activities as well as previous characterizations of the site. The possible exception to this is where wash-out activities may have resulted in rapid infiltration of materials into the unsaturated zone. Generally, fragmented munitions (both organics and metals) are best considered to be very localized, low grade sources that accumulate over some area. Major outstanding questions to be resolved in this investigation

are the density of the fragments as well as the extent of the affected area. The surveys to identify unexploded ordnance (UXO) in the study areas, as described in Section 3.1.3, will provide information on the UXO density and extent. This information may also be obtained from the Archive Search described in Section 3.1.1. In certain locations such as around gun positions, soils may be more uniformly affected by propellant materials. Outstanding questions in these locations is the concentration of materials in the soil as well as the lateral extent of the materials.

Given the high rate of infiltration likely to occur in the Impact Area and its environs, careful evaluation of the vertical transport of munitions-related material should be made. Two factors have the potential to limit the vertical migration to the water table: the relatively poor leachability of munitions materials from fragments and potential from reaction in, and sorption to, the unsaturated zone solids. The latter potential is especially important given the depth of the unsaturated zone at the Impact Area. While the original munitions fragments are likely to leach poorly regardless of conditions likely to be encountered, it is difficult to estimate the mobility of the materials once they enter water solution. The rate of sorption and degradation for munitions-related materials has been shown to vary substantially with site-specific conditions. Therefore, the vertical extent of munitions-related materials observed at the site will be important in refining the conceptual model. It will be important to consider the soil conditions and the means of introduction when evaluating migration through the unsaturated zone.

As materials leave the bottom of the unsaturated zone, they will enter the groundwater. Migration in groundwater will occur according to the distribution of hydraulic head and hydraulic conductivity within the aquifer. From the Impact Area, groundwater will ultimately flow toward one of the coasts. Interaction with downgradient fresh surface waters is possible. In the near field, there is a possibility that flow will have a downward component. As described by Masterson et al. (1996), the groundwater flow paths are affected by changes in lithology within

the aquifer. For this reason, it is difficult to predict the exact path of any potential groundwater plume. Groundwater transport velocities are generally believed to be relatively fast due to the high hydraulic conductivities of the various units. Flow to the north and west (the predominant flow direction from the Impact Area) is likely to be slower than to the east and south as the hydraulic conductivity in the moraines is lower than in the Mashpee Pitted Plain but the head gradients are similar. Within groundwater, munitions-related materials will be subject to sorption, degradation, and dispersion. The effectiveness of these processes at attenuating down gradient concentrations is not clear at this point in time.

3.0 TASK EVALUATION AND SCOPE

This study is being conducted to determine the effects of military operations on the groundwater beneath and emanating from the Training Ranges and Impact Area. The tasks are scoped to provide data on groundwater quality, verify the groundwater flow pattern in the study area, and provide for the preliminary evaluation of suspected source areas. This information will be used in the preliminary risk and groundwater quality evaluations. As more understanding of the hydrogeology of the area is gained, the scope of the study will be revised as needed. A draft Response Matrix is currently being reviewed by EPA to describe the decision tree for responding to issues resulting from the findings of the field investigations. In accordance with the Response Matrix, additional investigation wells and/or soil samples will be used to collect data needed to characterize the level and extent of any contamination that may exist; and collect geotechnical and hydrogeological data to formulate policies for the long range protection of groundwater beneath the training ranges and Impact Area.

The initial scope of work for the training ranges and Impact Area study will include the installation of 40 permanent and 12 semi-permanent ground water investigation wells; collection and chemical analysis of soil, surface water, storm water, sediments and groundwater samples; and the search for and review of records relating to the use of the site, fate and transport of suspected contaminants, and the general groundwater quality of the MMR. The investigation wells, supplemented by the LRWSPAT water source investigation test wells and selected IRP monitoring wells at the IRP sites around the study area, will provide control points for groundwater evaluation data that will be used to verify the groundwater flow model. Soil, surface water, storm water, and sediment samples will provide data for the preliminary evaluation of suspected sources; and groundwater samples will provide data for the evaluation of the quality of groundwater beneath the study area. Additional investigation of suspected sources may be considered if the initial data warrants it, and all additional investigation wells and/or soil

sampling locations will be determined in consultation with the EPA, according to the decision criteria contained in the Response Matrix for this study.

Figure 3-1 shows the proposed investigation well locations and potential zones of contribution for the long-range water supply sites 1,2,3 8, and 95-6/95-15. The locations of these wells were selected based on the current understanding of groundwater flow, anticipation of downgradient locations from the suspected source areas, and potential zones of contribution identified by the USGS based on groundwater modeling. The nested well locations are intended to investigate probable vertical gradients that may control fate and transport of contaminants. The wells located in the Impact Zone (Well nests 1,2, and 3, and wells 25, 26, and 27) will be semi-permanent, and the closure criteria will be agreed to with the EPA. These wells will be protected against accidental impact. and will exist long enough to characterize the aquifer.

The scope of the investigation will include the installation of investigation wells in and around the Training Range and Impact Area, the collection and analysis of environmental media, aquifer characterizations and the completion of a risk assessment. The new wells will be supplemented by selected IRP monitoring wells. This investigation well network will also include the potable water source investigation test wells installed by Stone and Webster earlier this year under contract to the Air Force Center for Environmental Excellence (AFCEE). The new and existing wells will be used to assess groundwater flow and quality beneath the training ranges and Impact Area.

Proposed locations for sampling soil, surface water, storm water, and sediment are summarized in Table 3-1. Soil samples will also be collected from monitoring well borings shown in Figure 3-1. The soil sampling at areas in Table 3-1 will be done on a grid system. The grids will be

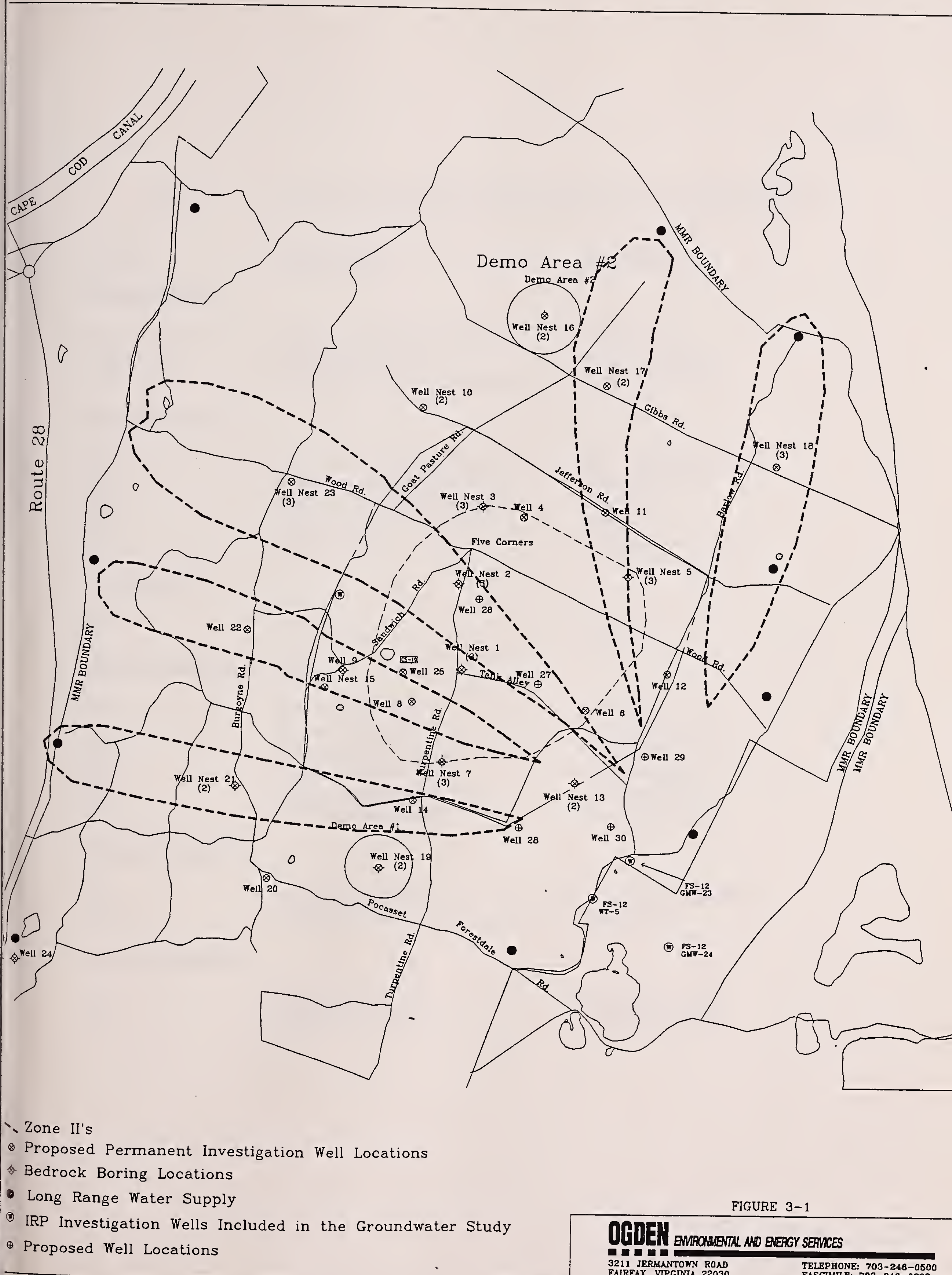

FIGURE 3-1

OGDEN ENVIRONMENTAL AND ENERGY SERVICES

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FAIRFAX, VIRGINIA 22030

TELEPHONE: 703-246-0500
FASCIMILE: 703-246-0939

Table 3-1 Proposed Locations for Sampling Soil, Surface Water and Sediments

NAME	DESCRIPTION	LOCATION
Target Area(Soil)		
Target Area 1 (Site 1)	Inclusive of all identified features	Central Zone
Target Area 2	Inclusive of Burn Area	South of 5 Corners
Target Area 3	Area of Depression with Ground Scar	North of 5 Corners
Identified Sites(Soil)		
CS-19(Site 2)	Inclusive of all identified features	East of Sandwich Road
Site 3	Inclusive of all identified features	SE of Target Area 2
Site 4	Inclusive of all identified features	Central Zone
Site 5	Inclusive of all identified features	SE Zone
Site 6	Disturbed Area	Monument Beach Road
Burn Areas(Soil)		
BA-XX	All Identified	Throughout
Gun and Mortar Positions(Soil)		
GP-9	High use gun position	Howe Road
GP-X	Low use gun position	To be determined
GP-X	Mixed use gun position	To be determined
MP-X	High use mortar position	To be determined
MP-X	Low use mortar position	To be determined
MP-X	Mixed use mortar position	To be determined
Demolition Areas(Soil)		
Demo-1	Topographic depression	Pocasset/Forestdale Road
Demo-2	Topographic depression and cleared area	Gibbs Road
Drainage Swales (Soil)		
NA	Topographic depression	NW of Snake Pond
NA	Topographic depression	North of Snake Pond

Table 3-1 (Continued)
Proposed Sampling Locations for Sampling Soil, Surface Water and Sediments

NAME	**DESCRIPTION**	**LOCATION**
Control Areas (Soil)		
NA	In the Impact Area	To be determined
NA	In the Impact Area	To be determined
NA	In the Impact Area	To be determined
NA	In the Impact Area	To be determined
NA	Near Gun Position	To be determined
NA	Near Mortar Position	To be determined
Ponds/Swamps (Surface Water, Sediments)		
Rod and Gun Club	Pond	SW of Impact Area
Deep Bottom	Pond	NW of Impact Area
Little Halfway	Pond	West of Impact Area
Donnely	Pond	West of Impact Area
Baileys	Pond	Burgoyne Rd., North of Woods Rd.
Gibbs	Pond	South of Demo Area-2
Grassy	Pond	Gibbs Rd., East of Demo Area-2
Ox	Pond	NE of Impact Area
Succonesette	Pond	South East Buffer Zone
Opening	Pond	Pocasset/Forestdale Road
Raccoon	Swamp	North of Impact Area
Round	Swamp	Burgoyne Road, North of Jefferson
Bypass Bog	Swamp	NW of Snake Pond
Drainage Swales (Storm Water)		
NA	9 Subwatershed Areas (See Figure 3-2)	Throughout

NA = Areas not named on existing maps

based on a review of aerial photographs and field observations to identify the most heavily used areas (focal zone) of the suspected areas for soil sampling. Sampling locations in ponds and drainage swales will be based on topography, visual field observations and historical use of the areas contributing flow to the drainage. Groundwater quality data will be collected from all the new wells, approximately 18 IRP wells, and the LRWSPAT test wells. Additional investigation at these sites will be based on the results of the archives search, analytical results, and other information.

The primary compounds of interest are those derived from munitions and their degradation byproducts. Therefore, the focus of the analytical program will be to identify compounds relating to explosives. Furthermore, the sampling and analytical programs will be designed to attempt to distinguish compounds derived from explosives, and those resulting from other activities not related to typical range activities. However, for completeness, and in order to comply with the MMR IRP Quality Assurance/Quality Control (QA/QC) guidelines for analytical programs for environmental investigations at MMR, the list of analytes will include Target Analyte List Inorganics (TAL inorganics), Target Compound List Volatile Organic Compounds (TCL VOCs), Target Compound List Semi-Volatile Organic Compounds (TCL SVOCs), TCL for Pesticides/PCBs, Herbicides, Ethylene Dibromide (EDB) and Methyl-Tert-Butyl-Ether (MTBE).

3.1 Investigation

The history of the numerous ranges, their use and types of munitions used over the years is uncertain. However, some previous investigations (USAEHA, 1987; USACHPMM, 1994) at typical ranges, artillery and mortar locations, and the CS-19 site (see Figure 3-1) located within the training range and Impact Area have provided insight on activities occurring in the study area.

3.1.1 Archives Search

The historical use of the Impact Area over the last 10 years has been well documented, but the previous 50 years was not. Identification and verification of the types and quantities of munitions used at MMR will include searching the Munitions Items Disposal Action System (MIDAS) database, primary supply depot records, databases from other military installations for the same periods, and interviews with former and current employees of the installation. The following information will be collected:

- The type of munitions used at the installation
- Time periods each munition was used, and the quantities per time period
- Physical and chemical components of each munition, including fuses
- Types and locations of the target for each munition
- UXO density based on percent duds and quantity used per area
- UXO depth based on historical range reports, the applications of the Army Corps of Engineers, Huntsville research models, and UXO surveys associated with the soil and groundwater sampling

In addition to munitions used, the archives search will include a review of all unconfirmed incidences of improper and/or accidental disposal of waste in the Impact Area, and a review of previous investigation at this and other installations with similar historic use patterns. These reviews will be compared to data from aerial photographs and interview with former and current employees to identify potential areas for environmental investigation.

Finally, the archives search will include a summary of information relating to the fate and transport of explosive compounds in the environment. This summary will include a review of the existing information on the site hydrogeology from previous investigations and groundwater modeling. Also data regarding the fate and transport of munitions-related chemicals under similar environmental conditions will be collected and summarized. This report will summarize

the references, rather than duplicate, the methodologies and findings of the previous investigations.

This task will be initiated with a meeting between NGB and EPA at MMR to discuss research methods and public involvement. Interim reports of the records search will be provided in project review meetings with NGB and EPA that will summarize information collected and schedule for work. Final results of the archives search will be documented in three reports, including

- The unexploded ordnance report will provide detailed information on the munitions used at the Impact Area;
- The historical range use report will provide detailed information on the prior use of the Impact Area and the potential for environmental impacts from these uses; and
- A summary of environmental fate and transport will present available information on site hydrogeology including well construction details and water quality results, a review of investigations at sites with similar environmental conditions, and the fate and transport of munitions-related chemicals.

Each document will include a description of the research methods, results and their interpretations, recommendations for additional work as necessary, and supporting information including maps, photographs, and drawings.

3.1.2 Review of Aerial Photographs

The data requirements of this project will include the review of new and historical aerial photographs. Aerial photographs will be analyzed to identify historically heavily used areas for soil sampling. These heavily used areas are the most probable sites where soil contamination may have occurred. An aerial photographic analysis of the Impact Area identified six probable sites, which included CS-19, and numerous other locations of interest for environmental investigation (ERI, 1994).

3.1.3 Unexploded Ordnance Survey

All access roads, investigation well and soil sampling locations will be surveyed and cleared for unexploded ordnance (UXO) before the investigation. The depth of UXO screening during boring for investigation well location or subsurface sampling will be determined based on Army Corps of Engineers guidance for subsurface investigations, and the professional judgment of the UXO clearing contractor. In addition to ensuring the safety of sampling personnel, the UXO survey results will provide information useful for estimating UXO density and extent in the sampling locations. The survey will provide numbers and types of UXO for selected portions of the Impact Area. These data can be supplemented with information from the Archive Search to estimated UXO density for the entire Impact Area.

3.1.4 Surface Water, Soil and Sediments Sampling

Table 3-1 summarizes proposed locations for surface water, surface soil, storm water, and sediments sampling. Natural depressions and swales will be investigated as probable conduits and areas of compound accumulation resulting from storm water run-off. Subsurface soil samples will also be collected during borehole completion for both permanent and semi-permanent investigation well installation. The locations for these investigation wells are shown on Figure 3-1.

3.1.4.1 Surface Water and Sediments Sampling

Surface water and sediment samples will be collected from nine ponds in the Training Range and Impact Area, one pond at the Rod and Gun Club, and three swamps. Most kettle holes in the study area are dry, and only collect water during and immediately after large rainstorms before it all infiltrates and/or evaporates (see Section 3.1.4.4 Storm water Sampling). However, the swamps and ponds appear to be deep enough to possibly intersect groundwater, and these will be sampled.

3.1.4.2 Soil Sampling

The soil sampling program will consist of a two tier program including:

(i) surface soil sampling, and

(ii) subsurface soil sampling and lithologic logging at investigation well locations.

Typical sampling and analysis protocols for these two tiers are presented in Section 4.0. Detailed sampling maps and sample numbers will be provided in a specific Field Sampling Plan for each area of concern. Several of these plans are provided as attachments to this Action Plan, and additional plans will be submitted for EPA approval prior to sampling.

3.1.4.3 Groundwater Sampling

Upon completion of investigation well installation, and after allowing enough time for stabilization, groundwater samples will be collected for analysis. Groundwater data will be collected from all newly installed wells, the nine LRWSPAT test wells (one of the ten is dry), the two Bourne Wells (95-6 and 95-16) and 18 IRP monitoring wells including eight from CS-19, six from FS-12, two from CS-18, and two from CS-1 (see Figure 2-6). Before sampling, the depth to groundwater in each well will be measured and recorded. That information will be augmented by water level measurement from USGS, IRP, and LRWSPAT monitoring wells in and around the study area. Groundwater sampling will be conducted using the July, 1996 EPA low stress (low flow) purge and sampling procedure.

3.1.4.4 Storm Water Sampling

Because of the sandy soils and lack of impervious surface within the Impact Area, there is very little storm water runoff as described in Section 2.2.1. Precipitation infiltrates into the sandy soils and becomes ground water recharge. Only the largest storm events will generate storm water runoff. Most kettle holes in the study area are dry, and only collect water during and immediately after large rainstorms before it all infiltrates and/or evaporates. Sediment samples

will be collected from areas where storm water flows off the Impact Area and from dry kettle holes within the Impact Area.

Based on the topographic map, nine (9) subwatershed areas within the Impact Area were determined as illustrated in Figure 3-2. Storm water will be sampled within each subwatershed at drainage swales or valleys, by collecting grab samples within the first 30 minutes of runoff from major storm events (>1 inch in 24 hours).

3.1.5 Investigation Well Installation

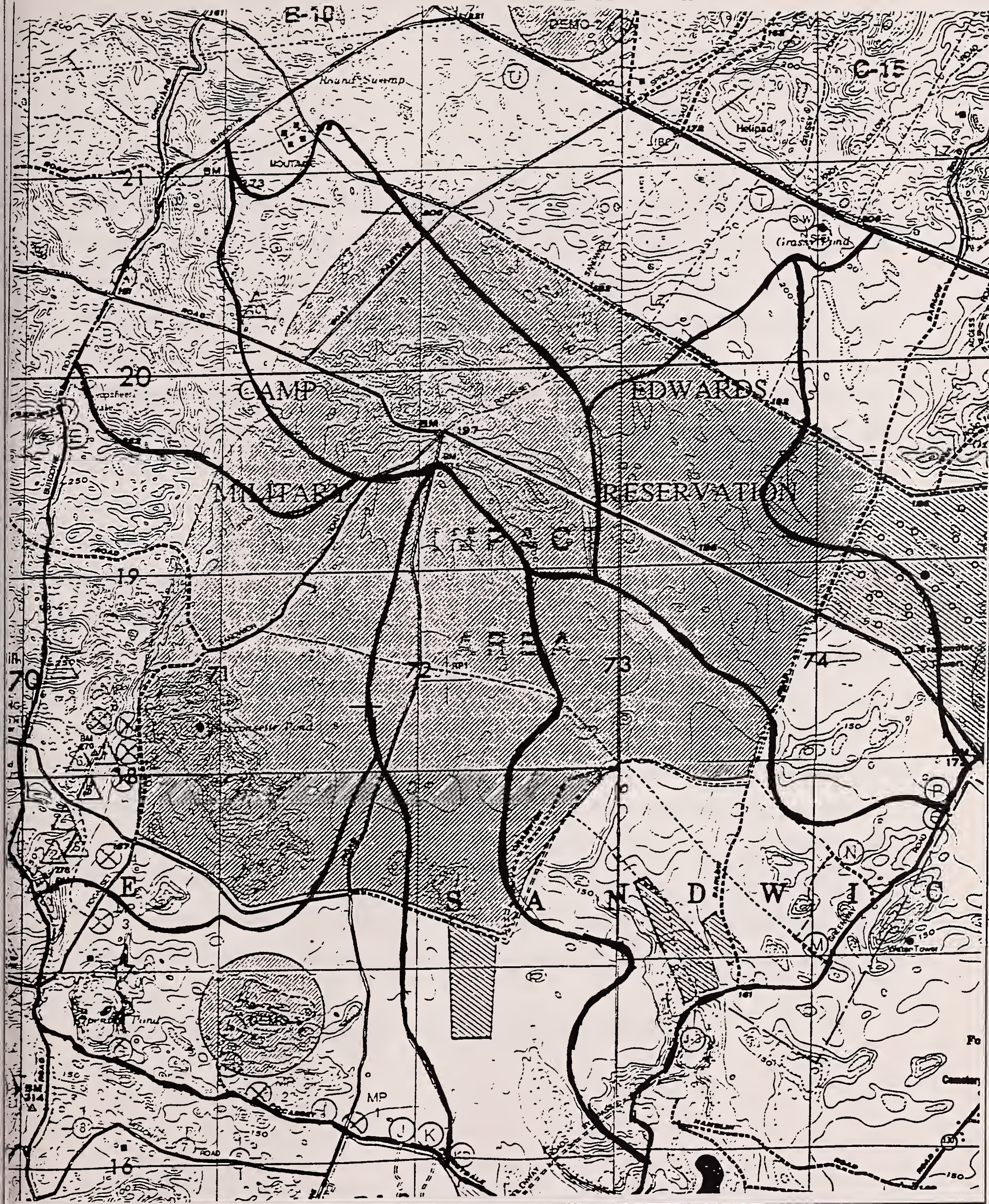
The scope of the investigation well installation will initially include 40 permanent and 12 semi-permanent wells. The number and locations of wells will be subject to change and revision in the field as data gathered is reviewed, and as we gain a better understanding of the hydrogeology of the site. All changes will be made in consultation with the EPA.

The monitor well installation program will be required to provide groundwater data collection points, and hydrologic control points to:

(i) Assess the quality of groundwater beneath the study area; and

(ii) Provide a good understanding of groundwater levels and movement -- both horizontal and vertical-- to help understand the flow of groundwater.

Initially, 30 locations have been selected to install 52 permanent wells (See Figure 3-1). At eight of these locations, a nest of three wells will be installed, including one screened at the water table, one screened above the silty clay layer if present, or otherwise above the bedrock, and one screened at an intermediate depth. The depth of the intermediate well will be determined by the results of laboratory analysis of groundwater samples collected during borehole drilling for installing the



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3458 ELLICOTT CENTER DRIVE SUITE 101
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BALTO. 461-0920 WASH. 921-4680

Figure 3-2
Subwaterseds

SCALE: CONTRACT NO.: DATE: SHEET:

deep well. At six of these locations, a nest of two wells will be installed, including one screened at the water table and one screened above the silty clay layer if present, or otherwise above the bedrock. All 14 of the deep well locations will be drilled 15 feet into bedrock. The recommended sites for drilling to bedrock are shown on Figure 3-1, and may be revised in consultation with the USGS and EPA.

At each nested well location, a boring will be drilled, and soil samples collected at 10 foot intervals in the unsaturated zone for lithology and head space screening. At deep borings below the water table, groundwater samples will be collected every 10 feet for screening and analysis to determine the water quality. Results of these analyses will be used to determine well depth and screen intervals for the intermediate depth well. If no contamination is present based on the screening analysis, a review of the lithology and hydrogeology will determine the screen interval. The depths of the remaining 16 single wells will be determined based on available data for the 36 nested wells. When no contamination is found based on the screening analysis at the nested well sites, depth of the 16 single wells will be set at the water table. This depth may change after review of the nested well lithology in consultation with the USGS and EPA.

Investigation wells will be drilled and installed by a driller under the supervision of a qualified geologist or hydrogeologist who will log the boring, collect and prepare samples, and document well completion. For purposes of this project, the hydrogeologist/field supervisor for the drilling program will be required to keep a detailed record of the daily activities. This record will include but is not limited to drilling conditions, problems encountered and the methods employed to resolve them, weather conditions, and any condition and/or activity bearing effects on data quality and procedures.

Well construction methods are detailed in SOPs referenced in Section 4.0.

3.1.6 Elevation and Location Survey of Investigation wells

After installation of the wells, a licensed surveyor will locate investigation wells installed during this investigation. The coordinates of the wells will be presented in the Massachusetts State Plane Coordinate System North American Datum of 1927. Vertical surveys of the wells will be based on the National Geodetic Vertical Datum of 1929. Horizontal accuracy of the survey will be within 0.1 feet, and vertical accuracy will be within 0.01 feet. Well stickup from ground surface will be determined for the well and protective casings with the same level of accuracy. A permanent marker will be placed at the points of measurement on each casing.

3.1.7 Well Site Clean-up and Restoration

After completion of field activities at all sampling and investigation well locations, all equipment and materials not associated with the well itself will be promptly removed. The area will be restored to its original condition by removing trash, excess grout and concrete and grading to remove ruts. Seeding, mulching and general landscaping may be required. Investigation Derived Waste (IDW) will be handled in accordance with the modified IRP SOPs as described in section 5.0 of this work plan.

3.1.8 Water Level Measurements

Subsequent to the completion of the survey, groundwater levels in the investigation wells will be measured and recorded using an electronic measuring device. The probe of the device is lowered into the well until it hits the water table. A continuous tone is emitted when the probe contacts water. The depth to water is read off the calibrated tape to which the probe is attached. Water levels will be measured with 0.01 foot accuracy; and the data, together with surveying data, will be used to generate a groundwater elevation map. Four rounds of synoptic water level measurements will be completed during the study, and the results used to evaluate positions of remaining

proposed wells. Also, dataloggers will be installed in wells at CS-18, CS-19, and a LRWS well to obtain continuous water level measurements over a period of several months.

3.1.9 Aquifer Testing

Aquifer testing plans will be developed in consultation with the EPA, MADEP, and other stakeholders as the study progresses. The objective of this testing will be to qualitatively determine aquifer parameters that control flow patterns and to determine the relationship between these flow patterns and the transport of any contamination that might exist. Further still, the results of this effort will be used to refine existing models to predict the regional flow and transport for the whole installation. The activities of this task may include slug and/or pumping tests to estimate hydraulic conductivity and determine the relative permeability and conductivity of the various strata being monitored at the site.

3.2 Preliminary Risk Evaluation

A Preliminary Risk Evaluation (PRE) will be conducted for each exposure area. A PRE is a screening-level risk assessment that supports risk management decision making. The PRE will identify those compounds of concern which are found in concentrations that may have potential adverse effects on humans and ecological receptors.

The PRE will be conducted using the Tier I procedure and guidelines provided in the MMR Risk Assessment Handbook, Volumes I and II, Massachusetts Military Reservation (CDM, September 1994), updated to meet the focus of this study. Preliminary risk evaluation screening procedures (Tier I) are designed to conservatively identify sites that require further investigation. They are designed to be conservative; identifying sites that, in fact, may not present any actual risk. A work plan for performing the PRE will be provided to the EPA before initiation of the risk evaluation.

3.3 Follow-on Actions

The following actions may be required to fulfill the goals of the EPA Region I Administrative Order.

3.3.1 Risk Assessments

The Army National Guard, in consultation with EPA, will complete human health risk and ecological risk assessments. The Army National Guard will partner with other federal agencies who are recognized experts in the risk assessment field. These agencies will work with the supervising contractor to gather information, augment existing data and complete the risk assessments. These risk assessments will include modeling the fate and transport of all contaminants found as a result of this investigation and will be used during the development of any required response plans and the long term monitoring program.

3.3.2 Response Plans

Response plans will be prepared and implemented as conditions warrant. Response plans will describe additional investigations needed to resolve issues identified during implementation of the Action Plan. All data evaluation will be conducted in consultation with EPA. At any time sample results indicate additional investigation is required at a particular site, the ARNG will direct the supervising contractor to prepare a response plan. The preparation of the response plan will be coordinated with EPA, MADEP and the IRP. ARNG will brief the citizens advisory committee of the need for and contents of the response plan. The response plan will be initiated immediately after receiving approval of the plan's contents from EPA.

3.3.3 Installation Response Program (IRP) Investigation Referral

Throughout the duration of this investigation, the ARNG will coordinate with the IRP. All data gathered during the investigation will be made available to the IRP. A partnership will be established with IRP to ensure all response plans are coordinated. In the event that a source of contamination is located and determined to be eligible for inclusion in the IRP, the partnership ensure that the proper investigation is conducted. The proper agency will develop any required response plan and will ensure all necessary actions are taken to comply with that plan.

3.3.4 Long Term Monitoring Program

After the initial data has been gathered and the groundwater model has been verified, ARNG will develop a long term monitoring program. This monitoring program will be developed in consultation with EPA, USGS, MADEP and the LRWSPAT. Additional input may be requested from the IRP and other federal agencies. The long term monitoring plan will be developed using the results of the groundwater modeling, the risk assessments and source evaluations. Additional permanent wells may be installed in support of the long term monitoring program.

4.0 Sampling Plan

4.1 Introduction

The following sampling procedures will be utilized during the Impact Area Groundwater Quality Study:

- surface soil sampling by hand auger
- subsurface soil sampling by hand auger and drill rig
- groundwater sampling by screened drill rod and monitoring well
- water level measurements by monitoring wells
- surface water sampling
- sediment sampling
- stormwater sampling

This section of the Action Plan provides sampling procedures (section 4.2), sample locations (section 4.3), numbers of samples and analytes (section 4.4), and record keeping requirements (section 4.5). Section 5.0 of the Action Plan describes decontamination and waste management procedures. A Quality Assurance/Quality Control (QA/QC) plan is provided in Appendix A. A Health and Safety Plan (HASP) is provided in Appendix E.

4.2 Sampling Procedures

Field Activities will be performed in accordance with the standard operating procedures (SOPs) employed by AFCEE under IRP ("Standard Operating Procedures for Environmental Investigations at MMR", CDM, 1993). The relevant SOPs for the activities listed in section 4.1 are summarized in Table 4-1. These SOPs will be subject to the modifications shown in Table 4-1.

Table 4-1. Summary of SOPs and Modifications

SOP	Activity	Modification
OTIS TECH-002	Monitoring Well Installation	Annular Seal will only be installed at confining intervals, otherwise the borehole will be allowed to collapse around the monitoring well
MMR TECH-004	Well Development	Development is complete when purge water parameters have stabilized within 10% for three consecutive readings.
MMR TECH-006	Static Water Level	Total Depth Measurements will not be performed during water level measurement. Therefore the requirement for any equipment used for total depth measurement is waived. Total Depth measurements will be taken from well construction diagrams.
MMR TECH-015	Groundwater Purging and Sampling	US EPA sampling protocol GW0001 will be used (see below).
MMR TECH-017	Surface Water Sampling	No modification.
MMR TECH-020	Field Filtering	No modification.
MMR TECH-021	Soil Sampling	Subsurface Soil Sampling - the hand auger will only be decontaminated at the start of the collection of composites from each interval. Barber Rig Deep Subsurface Soil Sampling - The cyclone will be used to collect soil samples from below the water table for lithology.
MMR TECH-022	Sediment Sampling	No modification.

Table 4-1 (cont) Summary of SOPs and Modifications

MMR TECH-025	Sample Management	Sample labels will be prepared by Sample Labeler^{tm} software. Chain of Custody (COC) records will be filled out manually, not by JESS system. Distribution of COC: 2 copies shipped with samples, others retained in project file. COC errors will be corrected, noted in logbook and copies forwarded to the lab and project file. The sample control logbook will consist of COC copies, airbills (if applicable), and comments.
MMR TECH-026	Chain of Custody	No modification.
MMR TECH-027	Preserving Environmental Samples in the Field	All sample containers will be pre-preserved by the lab with sufficient preservative to achieve the proper pH. Samples for EDB analysis will be preserved with sodium thiosulfate and 1:1 HCl to pH <2.
MMR TECH-028	Packing and Shipping of Samples	Each sample container will be wrapped in bubble wrap only and packed in the cooler.
MMR TECH-035	Field Logbook	The first five pages of the logbook will not be used for a table of contents.

Table 4-1 (cont) Summary of SOPs and Modifications

MMR TECH-036	Equipment Decontamination	Equipment will be decontaminated by the procedures: 1) Heavy Equipment - consists of scraping, brushing and washing with potable water and steam cleaning until exposed surfaces are free of soil residue; 2) Downhole Sampling Equipment - steam cleaned and air dried; 3) Pumps and Tubing (screening) - circulate potable water; 4) Groundwater Sampling (pumps) - circulate with Liquinox and water solution, followed by circulating with deionized water; 5) Reusable Sampling Equipment - remove visible contamination by brushing/wiping, wash and scrub with Liquinox and water solution, rinse with potable water, rinse with deionized water, rinse with methanol, air dry, and wrap in aluminum foil; 6) Reusable Protective Clothing and Equipment - wash with Liquinox and water solution, rinse with potable water.
MMR TECH-040	Headspace Analysis for VOC	The equipment for headspace analysis will be a Photovac mini-FID. A representative soil sample will be placed in a plastic bag and allowed to develop headspace for approximately 5 minutes.
MMR TECH-041	Dissolved Oxygen Measurements	An equivalent DO meter and flow-thru cell will be utilized. Calibration will be performed in accordance with the SOP or manufacturers specifications.
MMR TECH-043	Specific Conductance Measurements	Readings will be collected using a flow-thru cell. Calibration will be performed in accordance with the SOP or manufacturers specifications.
MMR TECH-044	Temperature Measurements	Calibration will be performed in accordance with the SOP or manufacturers specifications.

Table 4-1 (cont) Summary of SOPs and Modifications

MMR TECH-045	Turbidity Measurements	Calibration will be performed in accordance with the SOP or manufacturers specifications.
MMR TECH-047	pH Measurements	Calibration will be performed in accordance with the SOP or manufacturers specifications.
MMR TECH-048	Global Positioning	To be based on subcontractor SOP and review. Modifications will be noted in an addendum to the Action Plan.
MMR TECH-050	Radioactivity Surveys	Any changes to this SOP will be submitted as an addendum to the Action Plan.
US EPA GW0001	Low Stress (low flow) Purging and Sampling Procedure	No modification.

Specific protocols for sample screening and compositing are described in the following protocols contained in Appendix C, and are summarized below:

- C.1 Hand Auger Sampling Protocol
- C.2 Soil Boring Installation/Groundwater Profiling Protocol
- C.3 Surface water/Sediment/Storm water Sampling Protocol
- C.4 Groundwater Sampling Protocol

4.2.1 Hand Auger Sampling

Hand Auger sampling will occur at locations specified in the Field Sampling Plans, as described in Section 4.3. Within these areas 30 foot by 30 foot sampling areas will be established. The sampling areas will be subdivided into nine 10 foot by 10 foot grids. Nine hand auger sample locations will be established in the center of these grids.

Soil sampling will be cleared for UXO avoidance. All magnetic anomalies within these areas will be identified with red flags. Soil sampling will occur in an area that is free of red flags or the frequency is low enough to work safely. If the grid location has to be moved to accommodate safe work conditions, the new location will be noted.

4.2.1.1 Surface Soil Sampling (0-6")

Surface soil sampling will be performed using a hand auger to collect soil samples from 0-6 inches below ground surface. Prior to soil sampling at each location, the hand auger and all sampling equipment will be decontaminated per the procedure described in Section 5.0.

A soil sample from each of the 9 grid locations will be collected from 0-6 inches and screened by an FID to determine if volatile organic compounds (VOC) are present. A VOC sample will be

collected from the grid location based on the following hierarchy: 1) highest FID reading; or if none then 2) stained/discolored soil; or if none then 3) the center grid point in the sampling area. The VOC sample will be collected by returning to the designated area and advancing a hand-auger boring 1 foot from the original boring used for FID screening. The VOC sample will be removed directly from the hand auger and collected in the appropriate sample container.

The soil collected for FID screening from the 9 grid locations will be combined in a stainless steel bowl. This soil will be homogenized with a stainless steel spoon or trowel following EPA guidance. Soil samples will be collected from the bowl for analysis.

4.2.1.2 Subsurface Soil Sampling (18-24")

Subsurface hand auger samples will be collected at the same locations as the surface hand auger locations. A VOC sample will be collected from the same surface soil grid location that was sampled for VOC. The VOC sample will be removed directly from the hand auger and collected in the appropriate sample container.

Soil from all grid locations will be collected in a stainless steel bowl. After soil is collected from the last location, the soil in the bowl will be homogenized using a stainless steel spoon or trowel following EPA guidance. Soil samples will be collected from the bowl for analysis.

4.2.2 Soil Boring Installation/Groundwater Profiling

Soil borings will be advanced for the installation of monitoring wells at locations illustrated in Figure 3-1. As each soil boring is advanced, soil samples will be collected every 10 feet for geologic logging and for laboratory analysis. Groundwater profiling samples will be collected every 10 feet in the saturated zone for laboratory analysis. Three types of borings will be performed: UXO clearance (auger rig drilling), barber rig drilling, and rotosonic rig drilling.

4.2.2.1 UXO Clearance (Auger Rig Drilling)

A truck-mounted 4-1/4 inch hollow-stem auger (HSA) drill rig will be used to ensure subsurface UXO clearance at each well location within the Impact Area and the Buffer Zone. The HSA rig will drill to at least 10 feet below ground surface at each monitoring well location, or until native soil is encountered. For nested well locations, the rig will advance one boring for the shallow/deep well location and one boring for the medium well location.

The drilling area will be cleared for UXO intrusively to two feet below ground surface prior to initiation of drilling activities. Each well location will be cleared by advancing the augers in two foot intervals, removing the augers and inserting a section of 4" diameter PVC. If needed the rig will be moved away from the borehole to prevent magnetic interference. At that time the UXO subcontractor will perform a magnetometer survey of the borehole. If UXO is not encountered the PVC will be removed and the augers advanced to the next two foot interval. If UXO is encountered, a new borehole will be started. The borehole will be considered clear at 10 feet below the ground surface (UXO detection to at least 12 feet) unless in fill material, in which case the borehole will be extended until native soil is encountered.

4.2.2.2 Barber Rig Drilling

A dual-rotary Barber drill rig will be used to advance all monitoring well boreholes inside of, and immediately adjacent to, the Impact Area to minimize any potential subsurface vibrations from use of rotosonic drilling. Deep monitoring well boreholes will be drilled first at each well nest location. Soil samples will be collected at ten-foot intervals using a split-spoon sampling device until the water table is encountered. Below the water table, soil samples will be collected at ten-foot intervals from the Barber rig cyclone. At each deep boring, refusal will be confirmed by

advancing the borehole 15 feet into bedrock, and through reviewing the USGS bedrock map of the study area.

Soil samples from the unsaturated zone will be screened with an FID. If a positive reading is recorded on the FID, samples will be collected for analysis of organic (non-explosive) compounds.

Groundwater profiling samples will be collected at ten foot intervals below the water table using a submersible pump or bailer. At the appropriate depth groundwater will be allowed to infiltrate the drilling rod and will be pumped to the surface. All sampling equipment will be decontaminated per the procedure described in Section 5.0 prior to the collection of each sample.

Deep and shallow monitoring wells will be constructed in the same borehole at well nest locations. A separate borehole for the intermediate depth well will be drilled immediately adjacent to the deep borehole to a depth determined by laboratory results for the deep borehole. No borehole sampling will be done during the advancement of the intermediate depth borehole.

4.2.2.3 Rotosonic Rig Drilling

A rotosonic drill rig will be used to advance all monitoring well boreholes outside of the Impact Area. Deep monitoring well boreholes will be drilled first at each well nest location. Soil samples will be collected continuously until refusal. At each deep boring, refusal will be confirmed by advancing the borehole 15 feet into bedrock, and through reviewing the USGS bedrock map of the study area.

Groundwater profiling samples will be collected at ten foot intervals below the water table using a point sampling device. At the appropriate depth, the sampling device will be advanced in front of the borehole thereby allowing the collection of an undisturbed groundwater sample. All sampling equipment will be decontaminated per the procedure described in Section 5.0 prior to the collection of each sample.

All soil samples will be screened with an FID. If a positive reading is recorded on the FID, samples will be collected for analysis of organic (non-explosive) compounds.

Deep and shallow monitoring wells will be constructed in the same borehole at well nest locations. A separate borehole for the intermediate depth well will be drilled immediately adjacent to the deep borehole to a depth determined by laboratory results for the deep borehole. No borehole sampling will be done during the advancement of the intermediate depth borehole.

4.2.3 Surface water/Sediment/Storm water Sampling

Surface water, sediment, and storm water samples will be collected at locations specified in the Field Sampling Plans, as described in Section 4.3. At ponds and swamps the surface water sample will always be collected first to reduce the amount of sediment entrained in surface water. Surface water samples will be collected by immersing each sample container under the surface of the water until filled. The process will be repeated until all sample containers are filled. Storm water will be sampled by immersing sample containers in visible runoff.

Sediment samples will be collected using a stainless steel spoon and a stainless steel bowl. When the appropriate sample volume has been collected, any surface water will be decanted and the sediment will be transferred to the appropriate sample containers. All sediment sampling tools will be decontaminated between each sampling location as described in Section 5.0.

4.2.4 Groundwater Sampling

Groundwater sampling will be performed by EPA guidance GW0001 for low-stress (low-flow) purge and sampling procedure. Prior to collection of the groundwater sample a water level measurement will be collected. A submersible pump will be used to purge water from the monitoring well. Dedicated polyethylene tubing will be attached to the pump and used for purge

water discharge. After the pump is started, flow will be adjusted to prevent the water level in the well from being drawn down more than 0.3 feet. Water level readings and pump flow rates will be recorded every 3 to 5 minutes. Purge water will be continuously monitored for water quality parameters including pH, specific conductance, turbidity, dissolved oxygen and temperature. When these parameters have stabilized a groundwater sample will be collected. If these parameters do not stabilize in four hours, a groundwater sample will be collected at that time. Samples for VOC analysis will be collected first.

4.3 Sampling Locations

Each target area/site identified in Section 3 or in subsequent Archive Search results will have sampling locations identified in a specific Field Sampling Plan (FSP) for that area/site. FSPs for several of these areas are being provided as stand-alone attachments to this Action Plan, and FSPs for the remaining areas will be provided as these are developed based on archive search results, field reconnaissance, and surveying. The general protocol for establishing sampling locations is as follows:

- A focal area or areas of concern will be identified for each site, based on archive search results, field observations, and if necessary land surveys. These areas will be located to intersect potential sources of contamination.

- Each focal area for soil sampling will be marked with one or more 30-foot square grids. A minimum of five grids will be used to sample each acre of a given focal area. Sampling will proceed at grid intervals as described in Section 4.2. In the event that deep soil sampling is needed at a focal area, a borehole will be advanced and sampled as described in Section 4.2.

- For the gun and mortar positions of "high use", "low use", and "mixed use", the one-acre focal area would encompass both the firing area and the bag burning area at that particular position. In addition to the focal areas, "control" areas will be identified at locations which are not believed to be within the immediate area(s) of concern. There will be four control areas within the Impact Area and two control areas for the gun and mortar positions.

4.4 Sample Analytes

The analytical methods to be used for this study are summarized in Table 4-2.

Table 4-2. Summary of Analytical Methods

Parameter	Method	Matrix
TNT/DNT screen	CRREL	soil
TNT/DNT screen	8330 high level	water
RDX/HMX screen	CRREL	soil
RDX/HMX screen	8330 high level	water
Explosives	8330	soil
Explosives	8330	water
Metals	ILM04	soil
Metals	ILM04	water
Cyanide	ILM04	soil
Cyanide	ILM04	water
Volatiles	OLM03.2	soil
Volatiles	OLM02.1	water
Semivolatiles	OLM03.2	soil

Semivolatiles	OLM02.1	water
Pesticide/PCB	OLM03.2	soil
Pesticide/PCB	OLM02.1	water
Herbicide	8151	soil
Herbicide	8151	water
Phosphorous	365.2 modified	soil
Phosphorous	365.2	water
Nitrate/Nitrite	353.2 modified	soil
Nitrate/Nitrite	353.2	water
Ammonia	350.2 modified	soil
Ammonia	350.2	water
EDB/MTBE	8021	soil
EDB	504.1	water
MTBE	8021	water
Full TCLP	SW-846	soil
Full TCLP	SW-846	water
anions	300.0	water
TOC	415.1	water
DO	Hach Kit	water
hardness	130.1	water

Each target area/site identified in Section 3 or in subsequent Archive Search results will have sample analytes identified in a specific FSP for that area/site. FSPs for several of these areas are being provided as stand-alone attachments to this Action Plan, and FSPs for the remaining areas

will be provided as these are developed based on archive search results, field reconnaissance, and surveying. The general protocol for establishing sample analytes is as follows:

- For soil sampling at grid locations, each of the 0-6" and 18-24" composite soil samples will be analyzed for explosives (colorimetric) and inorganics (metals, cyanide, phosphorous, nitrate/nitrite, and ammonia). Volatile organics (VOC) analysis will be conducted on grab samples selected by headspace screening, as described in Section 4.3. The 0-6"composite soil sample will also be analyzed for all other analytes (i.e., semivolatile organics, pesticide/PCB, herbicide, EDB/MTBE).
- For soil sampling at grid locations, any composite soil sample obtained from within the Impact Area that shows detectable levels of explosives using colorimetric methods will be analyzed using EPA Method 8330. Overall, 10% of all samples (obtained from within and outside the Impact Area) that show detectable levels of explosives, and 5% of all samples showing no detectable levels of explosives, will be analyzed using EPA Method 8330.
- For soil sampling at grid locations, any 0-6" composite soil sample that shows detectable levels of any other analyte (e.g., pesticide/PCB) will result in a 18-24" composite soil sample for the same grid undergoing analysis for the detected compound(s).
- At drilling locations in the Impact Area and Buffer Zone the 0-6" and 18-24" grab samples will be analyzed as follows: both intervals for explosives (colorimetric, and by 8330 if explosives are detected) and inorganics, the 0-6" interval for all other analytes (semivolatile organics, pesticide/PCB, herbicide, EDB/MTBE), and the 18-24" interval for other analytes based on the results of the 0-6" interval. The 10-12' interval from drilling locations in the Impact Area and Buffer Zone will be analyzed for explosives (colorimetric, and by 8330 if explosives are detected), inorganics, and all other analytes. The 20-22' interval from these drilling locations will be analyzed for explosives (colorimetric, and by 8330 if explosives are detected) and inorganics, and for all other analytes if headspace screening indicates that VOC may be present. Deeper intervals from drilling locations in the Impact Area and Buffer Zone

will be analyzed for inorganics, for explosives if detected in the 10-12' or 20-22' intervals, and for all other analytes if headspace screening indicates that VOC may be present.

- At drilling locations outside the Buffer Zone the 0-6", 10-12', and deeper interval grab samples will be analyzed for VOC, semivolatile organics, pesticide/PCB, herbicide, and EDB/MTBE if headspace screening indicates that VOC may be present.
- Groundwater sample analyses for performing screening during drilling will include explosives (8330 High Level Direct Injection Method) and, for borings in the Impact Area or Buffer Zone, VOC.
- All samples from the first round of groundwater monitoring will be analyzed for VOC, semivolatile organics, pesticide/PCB, herbicide, EDB, MTBE, explosives (8330), inorganics, anions, total organic carbon, and dissolved oxygen (field test).

4.4.1 Performance Objectives for Colorimetric Analysis

Colorimetric testing methods will be used to screen soils for laboratory analysis using Method 8330 or, outside the Impact Area, to determine what further studies (including possible sampling and analysis by Method 8330) are required. Given these goals, it is necessary to establish that the results of the two testing protocols are in agreement.

Given that the decision criteria associated with the colorimetric method are discrete, i.e., detection requires an action regardless of the actual reported concentration, the correlation of colorimetric and Method 8330 findings above the reporting limits is not relevant. However, it is very important to know that few "false negatives" (analyses reported at non-detect using the colorimetric analysis that would have been detected using Method 8330) occur. Thus, a comparison of performance for samples resulting in non-detect using the colorimetric method will be done.

A dataset will be compiled consisting of colorimetric and 8330 analyses for which the colorimetric method resulted in a non-detect finding. The percentage of samples for which Method 8330 analyses revealed detectable levels of any explosive covered by the colorimetric method will then be calculated.. If the percentage of disparate findings is less than 20%, the colorimetric method will be viewed as performing adequately. If disparate findings exceed 20% an evaluation will be made to determine if any modifications would improve the concordance of detections. Sampling and analysis will then be conducted again using either the modification or Method 8330.

An alternative performance criterion may be established if it is possible to interpret the detection limit with respect to potential health, ecological, or groundwater impact. If the colorimetric method reporting limit is not associated with potential impact, because it is lower than human health (e.g. Preliminary Risk Evaluation limits) or ecological benchmarks, and it can be shown that such a concentration would not be associated with groundwater impact, the colorimetric method may be determined to be adequate, even if lower concentrations might be detected frequently using Method 8330.

4.5 Monitoring Well Construction

Deep monitoring wells will be set on top of bedrock or above the silty clay layer if present, approximately 400 feet below ground surface. Shallow monitoring wells will be screened at the water table, approximately 100-150 feet below ground surface. The intermediate depth monitoring wells will be screened at an interval based on soil and groundwater screening results from the installation of the boring for the adjacent deep monitoring well.

All monitoring wells will be constructed with 2.5-inch inside diameter Schedule 80 PVC. Well screens will be constructed of 0.010-inch slotted 2.5-inch inside diameter Schedule 80 PVC, 10 feet in length. A screen pack consisting of sand will be installed to two feet above the top of the

screen. The borehole will be backfilled by allowing the borehole to collapse around the monitoring well as the casing is removed. If confining layers are encountered during the installation of a monitoring well borehole, a bentonite slurry will be used to backfill the confining layer portion of the borehole.

Monitoring wells will be developed at least 7 days after installation to allow bentonite seals to stabilize. Wells will be developed per MMR TECH -004 and the following protocol. Sediment will be removed from the wells using an Eevac Airlift pump. Groundwater will then be purged using a submersible pump. Development water will be periodically monitored for pH, specific conductance, temperature and turbidity. Development will be considered complete when groundwater quality parameters have stabilized with 10% for three consecutive readings.

4.6 Water Level Measurements

Periodic water level measurements will be collected from monitoring wells in and around the Impact Area. Water level measurements will be collected per Jacobs Engineering SOP MMR TECH-006. A water-level meter marked in 0.01 foot increments will be used to measure the depth to the water table. The depth to water table will be measured to the surveyed elevation (top of casing) for each well. Well identifications, water level measurements, the time and date they were collected, will be noted on a water level collection form.

Periodic water level measurements will be collected in one day to ensure synoptic water level data. The data will be used to calculate water level elevations, which will be plotted on a base map. The data will be used to generate potentiometric maps of the aquifer.

4.7 Recordkeeping

Field log books will be maintained per MMR TECH-035. Daily entries will include date, weather, relevant observations, names and companies of all visitors to sampling areas. Boring logs, monitoring well construction logs and sampling logs will be maintained for each location. Samples will be noted on the appropriate log. Chain of Custodies will be completed for shipment of samples to the laboratory per MMR TECH-026.

5.0 DECONTAMINATION AND WASTE DISPOSAL

All equipment and tools will be cleaned before beginning the field work and during well installation and sample collection. All personnel will be protected as outlined in the Health and Safety Plan. This work will generate investigation derived wastes (IDW) that will need proper handling and disposal.

These investigation derived wastes will include drill cuttings from well installation, waste liquids from decontamination activities, well development and purge waters, unused sample bottles and used protective clothing and equipment. These wastes will be handled according to the following protocol.

5.1 Decontamination

The drilling contractor will provide an acceptable rig and support truck equipped with a steam cleaner, water tank, portable wash rack, and other equipment necessary to complete the drilling and well installation program. A decontamination pad for the heavier equipment (such as rigs, augers and rods) and a staging area for supplies will be constructed at a location approved by the MMR Range Management Office. All drill rigs, construction equipment and tools will be cleaned before beginning the field program. All decontamination will take place at the decontamination pad except for reusable sampling equipment, which may be decontaminated at the drilling location.

Decontamination procedures will follow the SOP for environmental investigations at MMR (CDM, 1993) Cleaning of heavy equipment will consist of scraping, brushing, washing with potable water and steam cleaning until exposed surfaces are free of soil residue. All downhole sampling equipment will be steam cleaned and rinsed with deionized water, and air dried. Pumps and tubing used for sampling groundwater during drilling for screening analysis will be decontaminated by circulating potable water in the pump and submersible lines. Pumps used for

normal groundwater sampling will be decontaminated by circulating a Liquinox/water solution through the pump, followed by a deionized water rinse. Tubing will either be dedicated or discarded after each sample.

Reusable sampling equipment will be decontaminated according to the following procedure:

- Remove visible contamination by brushing or wiping with a cloth;
- Wash and scrub with an Liquinox/water solution;
- Rinse with potable water;
- Rinse with deionized water;
- Rinse with methanol; and
- Air dry and wrap equipment in aluminum foil.

Reusable protective clothing and equipment (such as gloves, boots and hard hats) will be decontaminated as follows:

- Wash with an Liquinox/water solution
- Rinse with potable water;
- Rinse with distilled water; and
- Air dry and store in a polyethylene bag to prevent contamination during storage or transport.

5.2 Waste Disposal

The investigation and decontamination process will generate wastes that require proper handling and disposal. The following is an outline of the appropriate handling procedures for each of these waste streams.

5.2.1 Personal Protective Equipment (PPE)

All used PPE will be segregated based on the judgment of the field supervisor as to whether they are hazardous waste or trash. PPE contaminated with hazardous waste will be drummed and stored at the central staging area for proper disposal. PPE not contaminated by hazardous waste will be disposed of as general trash.

5.2.2 Soil

The soil boring and investigation well installation programs will generate soil cuttings. Samples of the soils will be screened for volatile organic compounds by an FID instrument, using the headspace screening method. Soil cuttings will be stockpiled at the surface at each well location and left in place if headspace screening results for discrete samples using an FID are less than 5 ppm above background, and results of explosives analysis on a composite sample using EPA method 8515 and the CRREL colorimetric method indicate levels less than two times local surficial background levels determined from a composite sample. In the event that soil cuttings do not meet these criteria, the IRP SOP for soil classification for disposal will be followed. Soil cuttings that are containerized rather than left on site will be analyzed for VOCs, SVOCs, herbicides, pesticides, and metals after consolidation of like materials, in accordance with IRP SOP. Cuttings to be containerized will be drummed in a plastic-lined, DOT-approved, open-end sealed 55-gallon steel drum. Recycled drums may be used; however, the liner must be new and water tight. For tracking, all drums will be labeled with an identification number, the place of origin (soil boring or well designation) and content. Materials from different borings will not be combined in the same drum, nor will solid and liquid wastes be placed in the same drum.

All drums containing investigation derived soil cuttings will be transported to the central staging area. Disposition will be the responsibility of the Massachusetts Army National Guard (MAARNG).

5.2.3 Water

Drilling water, well development water, and purge water generated at each well location will be treated at the location by passing it through two granular activated carbon canisters in series and discharging the treated water to the ground surface. Water samples will be collected from the discharge port of the first canister at a frequency of one sample for every 2000 gallons of water treated. These samples will be analyzed for explosive chemicals to ensure that no contaminated water is returned to the aquifer.

Decontamination solutions will be containerized in DOT-approved 55-gallon steel drums. These solutions will be tested for RCRA characteristics after consolidation of like materials. Drums will be staged at a designated area, and disposition will be the responsibility of the MAARNG.

6.0 SITE-SPECIFIC QUALITY CONTROL AND HEALTH AND SAFETY PLAN

The field work for this project will be conducted within the guidelines of the MMR Standard Operating Procedures (SOP), Quality Assurance/Quality Control (QA/QC) and the general Health and Safety Plan (HASP). However, these generic plans will be amended through addenda to address site and project specific requirements. Only the addenda are discussed and provided as appendices to this work plan. The original documents are made part of this document by reference.

6.1 Quality Assurance Project Plan

Appendix A is a detailed, project-specific QA/QC plan. It details the QA/QC measures that will ensure that the data quality objectives of this project are met. A systematic data validation process will ensure the data are adequate for their intended application and use.

6.2 Health and Safety Plan

A site-specific health and safety plan is provided in Appendix E. All personnel who work in the field will be required to have completed the 40 hour Occupational Safety and Health Administration (OSHA) Hazardous Waste Site Investigation Training and have current certification. In addition, a baseline and exposure history will be maintained for all personnel through a medical surveillance program. The health and safety officer will maintain and document such records. The anticipated level of worker protection is Level D, but all field personnel will be prepared to upgrade to a modified Level D or Level C. For that purpose, sufficient safety equipment will be maintained on site for all personnel to provide for appropriate protection as determined by the on-site health and safety officer. At a minimum, the following safety equipment must be available for all personnel on site:

- Safety goggles;
- Hard hats;
- Chemical resistant/Tyvek coveralls;
- Steel-toed work boots;
- Disposable rubber gloves;
- Full-face air purifying respirators; and
- Adequate supplies of GMC-H APR cartridges.

The field supervisor or his designate will conduct a daily safety meeting for each field activity. The supervisor also will be responsible for instituting the necessary supplemental safety procedures.

7.0 PROJECT MANAGEMENT AND SCHEDULE

7.1 Project Management

Figure 7-1 is a chart showing the organizational structure for this project. This project is being conducted under an administrative order from EPA Region I. Therefore, the scope of work and schedule have been developed in consultation with the EPA, who will also feature prominently in the management and approval of the fieldwork and any changes thereto. A brief description of the responsibilities of each entity and key personnel is provided below.

7.1.1 Organizational Structure

The overall responsibility for the program rests with the National Guard Bureau through the Project coordinator, LTC Richard Murphy. His responsibility will be to monitor the progress of the program, review and approve all work products and deliverables, monitoring the financial and schedule control, and instituting corrective action, if necessary.

The counterpart is the EPA technical project manager, Ms. Jane Dolan. She will be responsible for ensuring that the quality and schedule of the work meets the requirements of the administrative order; and will also be responsible for controlling the release of information to the public and special interest groups. The EPA project coordinator will also work with the NGB project coordinator and other regulatory agencies to ensure that their needs and opinion are reflected in the conduct of the program.

The primary consultant to the NGB for completion of this program is Ogden Environmental and Energy Systems (OGDEN). They will be responsible for supervising the fieldwork and

documenting the data and information collected to ensure the technical integrity of the study. By contract, OGDEN will supervise several subcontractors who will provide specialty expertise to various tasks of the program. The OGDEN Project Manager will be Mr. Marc Grant. Mr. Grant will work directly with the NGB project coordinator, and will be responsible for project staffing and direct management of all staff and subcontractor assignments to the project. In this role, the OGDEN project manager will be responsible for ensuring that the NGB and EPA project coordinators are kept informed of the technical and schedule progress of the project.

The OGDEN Field Program Manager will be Mr. John Rice, who will be responsible for executing investigation activities. The OGDEN Assistant Field Program Manager, Mr. Sam Farnsworth, will also be on-site during field activities. The OGDEN laboratory coordinator will be Ms. Elizabeth Wessling, who will be responsible for data validation, data management, and laboratory oversight. Other key Ogden personnel will be identified to EPA as needed during the performance of field investigations.

7.1.2 Subcontractors

OGDEN will subcontract with some specialty services providers to facilitate the completion of this program. In putting the team together, OGDEN will select team members to provide enough flexibility, technical know-how and experience with the specifics of the project to ensure quality service to the study. Bid specifications for each contractor will incorporate the requirements of this Action Plan. OGDEN will provide contractor oversight and auditing to ensure compliance with these specifications.

Particular attention will be paid to the specialty functions of the program, so that the selected team members have proven experience and strong staff capabilities in the specialty areas of the project for which they were chosen.

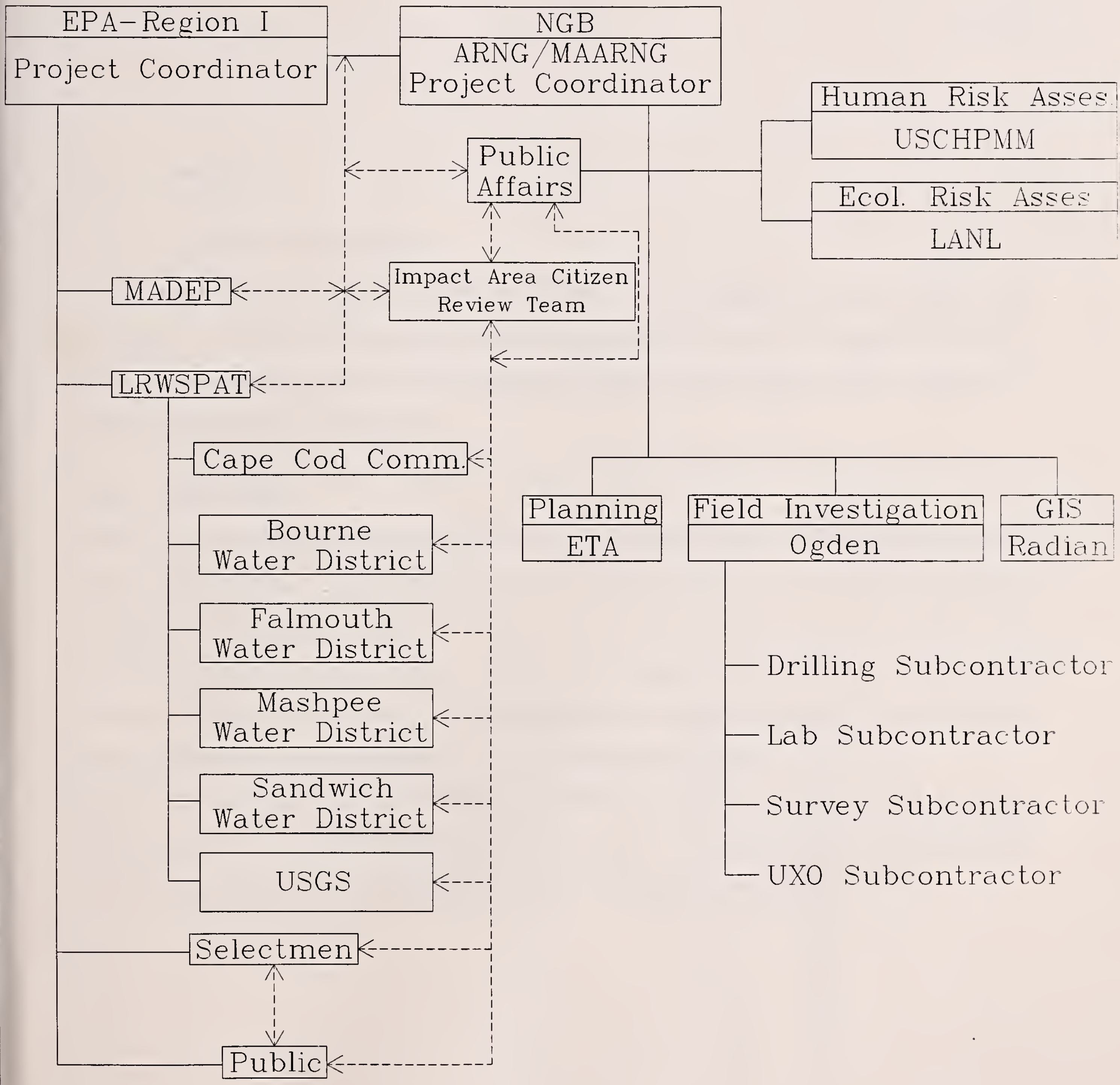

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Figure 7-1
Organizational Chart

SCALE:	CONTRACT NO.:	DATE:	SHEET:

7.2 Schedule

7.2.1 Overall Project Schedule

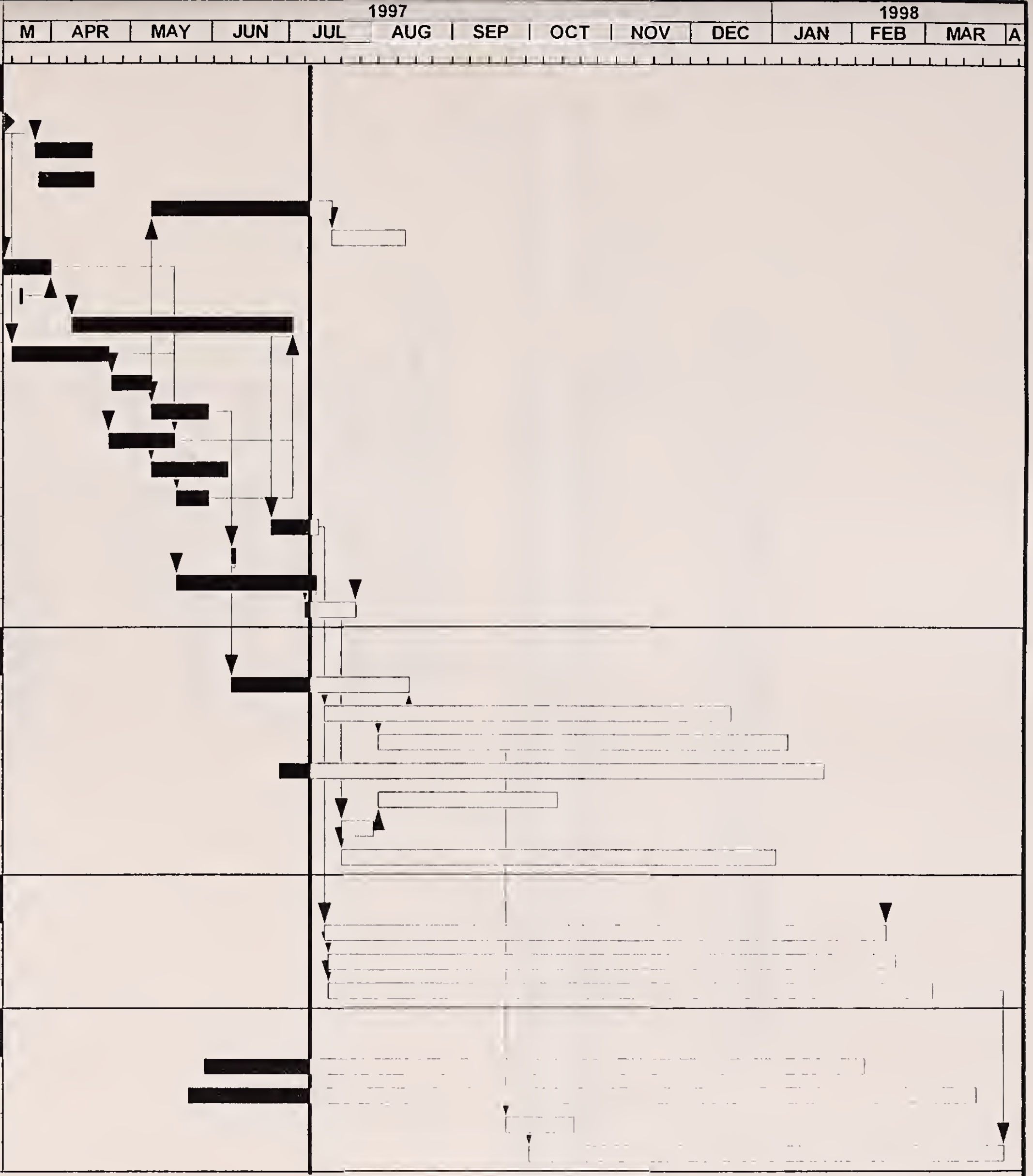
The overall project schedule is shown in Figure 7-2. The proposed project schedule was developed according to the requirements of the administrative order, and in consultation with the EPA. Any scheduling problems will be resolved at the project coordination level between the NGB and EPA project coordinators.

7.2.2 Deliverables

The primary project deliverable will be the site characterization report. OGDEN will prepare and submit this report as a draft report, a draft final and final report. The report will include a summary of the methodologies and activities conducted, a summary of the results of the literature search and review, and an evaluation and interpretation of the data collected. The conclusions drawn from the study and the inferences made from the data will be included; and recommendations made as to the follow on investigation, if necessary.

Data will be provided to EPA, MADEP, and other stakeholders on a weekly or biweekly basis during the course of the field investigations. In addition, several submittals of interim reports and plans are anticipated as discussed elsewhere in these comment responses.

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
Planning				
005	Submit Workplan for Public Comment	0	14MAR97A	
009	UXO Survey Bid Preparation	15	26MAR97A	15APR97A
010	Drilling/Laboratory Bid Preparation	15	27MAR97A	16APR97A
015	Archive Report: Draft Ranges/Munitions	35	09MAY97A	16JUL97
017	Archive Report: Draft Fate & Transport	20	17JUL97	13AUG97
020	Public Comment Period	12	14MAR97A	31MAR97A
023	Public Meeting	1	20MAR97A	20MAR97A
024	NGB/Ogden Prepare Scope of Work	20	09APR97A	01JUL97A
025	EPA Comment/Approval/Disapproval	2	17MAR97A	22APR97A
026	NGB/Ogden Prepare Interim SOW	10	24APR97A	08MAY97A
027	Ogden Arrange UXO Subcontract	5	09MAY97A	30MAY97A
030	Revise Draft Work Plan	10	23APR97A	17MAY97A
035	Mobilize for Field Investigations	10	09MAY97A	06JUN97A
037	Ogden Finalize Drilling/Lab Bids	10	19MAY97A	30MAY97A
038	Ogden Arrange Drilling/Lab Subs	5	24JUN97A	11JUL97
040	Investigation Kickoff Meeting	1	09JUN97A	09JUN97A
042	Revise Draft Final Work Plan	30	19MAY97A	10JUL97A
046	Prepare Field Sampling Plans	15	07JUL97A	25JUL97
Field Investigations				
050	UXO Survey	30	09JUN97A	15AUG97
100	Monitoring Well Installations	112	14JUL97	16DEC97
105	Well Development/Sampling	112	04AUG97	06JAN98
150	Synoptic Water Table Measurements	150	27JUN97A	20JAN98
200	Surface Soil Sampling	50	04AUG97	10OCT97
210	Surface Water & Sediment Sampling	10	21JUL97	01AUG97
220	Storm Water Sampling	120	21JUL97	02JAN98
Data Evaluation				
300	Laboratory Analysis & Data Mngmnt.	155	14JUL97	13FEB98
330	Evaluation of Response Actions	155	16JUL97	17FEB98
340	Risk Assessment	165	16JUL97	03MAR98
Reports and Meetings				
501	Project Review Meetings	152	29MAY97A	05FEB98
550	Monthly Progress Reports	213	23MAY97A	20MAR98
560	Interim Results Report	20	22SEP97	17OCT97
600	Completion of Work Report	130	01OCT97	31MAR98



Project Start	14MAR97
Project Finish	31MAR98
Data Date	09JUL97
Run Date	09JUL97

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Early Bar
▬ Progress Bar

MMR4

Sheet 1 of 1

National Guard Bureau
MMR Groundwater Quality Study
Schedule as of 7/9/97

Revision Number

Date	Revision	Checked	Approved

8.0 RECORD KEEPING AND REPORTING

8.1 Record Keeping

All field activities will be recorded in bound notebooks with sequentially numbered pages or on field log forms. At a minimum, the following information will be entered in the field notebooks or logs:

(i) Surface/Sediment Sampling Data

- Sample location designations
- Depth of sample location
- Visual classification of soils
- Date and time of collection
- Type of container
- FID reading
- Date of shipment to laboratory
- Sampler's name
- Notes regarding unusual conditions

(ii) Subsurface Soil Sampling

- Soil boring designation
- Visual classification of soils (unified system)
- Depth to groundwater
- Date of boring
- Interval/depth of sample
- Date and time of collection
- Field weather conditions

- Analysis required
- Date of shipment to laboratory
- Sampling method
- Sampler's name
- Notes regarding unusual conditions

(iii) Groundwater Investigation well data

- Investigation well designation
- Surface coordinates, top of casing elevation, depth of borehole and depth of well
- Visual soil classification
- Depth to groundwater
- Date of installation
- Boring and well completion logs
- Well development logs
- Field weather conditions
- Notes regarding unusual conditions

(iv) Groundwater Level Measurements

- Well designation
- Date and time of measurement
- Well depth
- Static water elevation
- Type of measuring equipment used
- Technician's name
- Notes regarding unusual conditions

(v) Groundwater Sample Data

- Well designation
- Well depth and static water level
- Well volume and required purge volume
- Type of container and preservatives
- Types and makes of sampling equipment
- Monitoring equipment readings
- Date and time of collection
- Analysis required
- Date of shipment to laboratory
- Sampler's name
- Notes regarding unusual conditions

All entries in the field notebook and the field logs will be made in indelible black ink. Corrections will be made by drawing a single line through the error and initialing and dating the correction. Individuals making entries will sign and date the bottom of each page of the notebook. All field log books will be legible.

8.2 Reporting

Upon completion of sample collection and analysis, the results of field observations and laboratory analysis will be summarized in a draft report. This report will consist of a summary of the data, field procedures used and the inferences drawn from the data to identify probable sources, and current status of groundwater quality. It will also recommend the next step for characterization of the site.

The following is a report outline:

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9.0 REFERENCES

1. CDM, Standard Operating Procedures for Work to be Performed at MMR, September 1993.

2. ABB Environmental Services, Inc., "Site Assessment, Work Completion Report-Chemical Spill Site in Impact Area, Massachusetts Military Reservation, Cape Cod," November 1992.

3. USAEHA, HSHB-ME-SH, "Interim Report, Hazardous Waste Study No. 37-26-0165-87, Investigation of Soil Contamination from Propellant Burns, Camp Edwards, Massachusetts, 25-29 June and 14-15 July, 1987," September 1987.

4. USAEHA, "Site Inspection Workplan, Geophysical Study No. 38- 26-K33U-95, Sites CS-18 and CS-19, Massachusetts Military Reservation, Cape Cod, Massachusetts," June 1994.

5. USACHPPM, "Draft Final Site Inspection, Geophysical Study No. 38-26-0278-95, Propellant Burning at Firing Points (CS- 18), Massachusetts Military Reservation, Cape Cod, Massachusetts," June 1996.

6. ERI, "Aerial Photographic Site Analysis, Massachusetts Military Reservation Impact Area, Barnstable County, Massachusetts," March 1994.

7. USACHPPM, “Draft Final Site Inspection Report No. 38-26- 1339-95, Site CS-19, Massachusetts Military Reservation, Cape Cod, Massachusetts,” June 1996.

8. IRP, “Risk Assessment Handbook, Massachusetts Military Reservation, Cape Cod, Massachusetts,” September 1994.

9. Letter, USAEHA, HSHB-ES-H, “Groundwater Monitoring Study No. 38-26-0457-86, AMC Open Burning/Open Detonation Facilities,” October 1985.

10. Schuh, W. M., “Planning, Construction, and Initial Sampling Results for a Water Quality Monitoring Program: Camp Grafton South Military Reservation, Eddy County, North Dakota,” North Dakota Water Resource Investigation No. 27, 1994.

11. Metcalf & Eddy, Inc., “Installation Restoration Program: Phase I Record Search,” Otis Air National Guard Base, Massachusetts, 1983.

12. Bricka, R. M., “Draft Report for Review, Investigation of the Vertical Migration Potential of Metal Contaminants at Small Arms Firing Ranges at Camp Edwards Military Reservation,” March 1996.

13. U.S. Environmental Protection Agency (USEPA), July 1996, Soil Screening Guidance: User’s Guide, Office of Solid Waste and Emergency Response, Publication 9355.4-23.

14. U.S. Environmental Protection Agency (USEPA), January 1996, “Ecotox Thresholds," ECO Update, Office of Solid Waste and Emergency Response, Publication 9345.0-12FS.

15. McGrath, October 1996, updated version of Physical, Chemical, and Environmental Data for Common, Explosive- Associated Compounds (XACs) tables.

16. Townsend and Meyers, 1996, Recent Developments in Formulating Model Descriptors for Subsurface Transformation and Sorption of TNT, RDX, and HMX, Technical Report IRRP-96- 1, U.S. Army Corps of Engineers Waterways Experiment Station.

17. Gunnison, Pennington, Price and Myrick, 1993, Screening Test and Isolation Procedure for TNT-Degrading Microorganisms, Technical Report IRRP-93-2, U.S. Army Corps of Engineers Waterways Experiment Station.

18. Honeycutt, Jarvis, and McFarland, 1996, "Cytotoxicity and Mutagenicity of 2,4,6-Trinitrotoluene and Its Metabolites", Ecotoxicology and Environmental Safety, Vol 35, pp. 282-287.

19. Pennington and Patrick, 1990, "Adsorption and Desorption of 2,4,6-Trinitrotoluene by Soils", Journal of Environmental Quality, Vol. 19, No. 3, pp. 559-567.

20. Jacobs Engineering Group, 1997, Massachusetts Military Reservation Inorganics Investigation Technical Memorandum, draft, Document # AFC-J- 23-35K78411-M17-001, prepared for HQ AFCEE/MMR.

21. Brannon and Myers, 1997, USCOE Waterways Experiment Station, Review of Fate and Transport Processes of Explosives, Technical Report # IRRP-97-2

22. Crockett, Craig, Jenkings and Sisk, 1996. Field Sampling and Selecting On-site Analytical Methods for Explosives in Soil, Federal Facilities Forum Issue USEPA/540/R-97/501.

23. Jenkins, Grant, Brar, Thorne, Ranney and Schumacher, 1996, Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at Explosive-Contaminated Sites, CRREL Special Report # 96-15

24. Kaplan, D., 1995, Biotechnology and Bioremediation for Organic Energetic Compounds, U.S. Army Natick Research, Development and Engineering Center, Research Paper # 95-41407-0-3

25. Xue, S. K., 1995, Adsorption-Desorption of 2,4,6-Trinitrotoluene and Hexahydro-1,3,5-Trinito-1,3,5-Triazine in Soils, Soil Science 160(5): 317-327

26. Xue, S. K., 1995, Transport of 2,4,6-Trinitrotoluene and Hexahydro-1,3,5-Trinitro-1,3,5-Triazine in soils, Soil Science 160(5):325-339

27. Walsh, Collins,and Racine, 1996, Persistence of White Phusphorus Particles in Salt Marsh Sediments, Environmental Toxicology and Chemistry, Vol. 15, No. 63, pp. 846-855

28. Brannon, Myers, Adrian, Pennington, and Hayes, 1992, Slow release of PCB, TNT, and RDX from soils and Sediments, Technical Report EL-93-38, U.S. Army Waterways Experiment Station, Vicksburg, MS.

29. Jenkins, T.F. et al. 1996. Assessment of sampling error associated with collection and analysis of soil samples at explosives-contaminated sites. Cold Regions Research & Engineering Laboratory. Special Report 96-15. September 1996.

30. Jenkins, T.F. 1997. Personal communication with M. Gerath of Ogden Environmental and Energy Services. April 23, 1997.

31. Masterson, J.P. et al. 1997. Hydrogeologic framework of western Cape Cod, Massachusetts. US Geological Survey. Open File Report 96-465.

32. Masterson, J.P. et al. 1996. Use of particle tracking to improve numerical model calibration and to analyze groundwater flow and contaminant migration, Massachusetts Military Reservation, Western Cape Cod, Massachusetts. US Geological Survey. Open File Report 96-214.

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